REPORT

OF THE

EIGHTY-FOURTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

AUSTRALIA: 1914

JULY 28—AUGUST 31

LONDON
JOHN MURRAY, ALBEMARLE STREET
1915

Office of the Association: Burlington House, London, W.

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OFFICERS AND COUNCIL, 1914–1915.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

PROFESSOR WILLIAM BATESON, M.A., F.R.S.

VICE-PRESIDENTS.

His Excellency the Governor-General of the Commonwealth of Australia.
Their Excellencies the Governors of New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania.
The Honourable the Prime Minister of the Commonwealth.
The Honourable the Premiers of New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania.
The Right Honourable the Lord Mayors of Sydney and Melbourne.
The Right Worshipful the Mayors of Brisbane, Adelaide, Perth, Hobart.
The Chancellors of the Universities of Sydney, Melbourne, Adelaide, Tasmania, Queensland, Western Australia.

PRESIDENT ELECT.

Professor ARTHUR SCHUSTER, PH.D., SEC.R.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord Mayor of Manchester.
The Right Hon. LORD SHUTTLEWORTH, LL.D., Lord-Lieutenant of Lancashire.
The High Sheriff of Lancashire.
The Right Hon. VISCOUNT MORLEY OF BLACKBURN, O.M., D.C.L., F.R.S., Chancellor of Manchester University.
His Grace the DUKE OF DEVONSHIRE.
The Right Hon. the EARL OF DERBY, K.G.
The Right Hon. the EARL OF ELLESMERE, M.V.O.
The Right Hon. VISCOUNT BRYCE, D.C.L., LL.D., F.R.S.
The Rt. Rev. the Bishop of Manchester.
The Chancellor of the Duchy of Lancaster.
The High Sheriff of Cheshire.
The Worshipful the Mayor of Salford.
The Right Rev. the Bishop of Salford.
The Right Hon. Sir H. E. ROSCOE, Ph.D., D.C.L., F.R.S.
The Right Hon. Sir WILLIAM MATHER, LL.D.
The Vice-Chancellor of the University of Manchester.
Sir EDWARD DONNER, Bart., LL.D.
Sir FRANK FORBES ADAM, C.I.E., LL.D.
Alderman Sir T. THORNHILL SHANN, J.P.
Professor HORACE LAMB, D.Sc., F.R.S.
R. NOTON BARCLAY, Esq.

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Professor W. A. HERDMAN, D.Sc., F.R.S. | Professor H. H. TURNER, D.Sc., D.C.L., F.R.S.

ASSISTANT SECRETARY.

O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W.

LOCAL TREASURER FOR THE MEETING AT MANCHESTER.

Alderman EDWARD HOLT, J.P.

LOCAL SECRETARIES FOR THE MEETING AT MANCHESTER.

Professor S. J. HICKSON, D.Sc., F.R.S. | Principal J. C. MAXWELL GARNETT, M.A.
Councillor E. D. SIMON, M.I.C.E.

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BRABROOK, Sir EDWARD, C.B.
BRAGG, Professor W. H., F.R.S.
CLERK, Dr. DUGALD, F.R.S.
CRAIGIE, Major P. G., C.B.
CROOKE, W., B.A.
DENDY, Professor A., F.R.S.
DIXEY, Dr. F. A., F.R.S.
DIXON, Professor H. B., F.R.S.
DYSON, Sir F. W., F.R.S.
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MYRES, Professor J. L., M.A.
RUTHERFORD, Sir E., F.R.S.
SAUNDERS, Miss E. R.
STARLING, Professor E. H., F.R.S.
TEALL, Dr. J. J. H., F.R.S.
THOMPSON, Dr. SILVANUS P., F.R.S.
WEISS, Professor F. E., D.Sc.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord RAYLEIGH, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Sir ARTHUR W. RÜCKER, M.A., D.Sc., LL.D., F.R.S.
Major P. A. MACMAHON, D.Sc., LL.D., F.R.S., F.R.A.S.

PAST PRESIDENTS OF THE ASSOCIATION.

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Sir H. E. Roscoe, D.C.L., F.R.S.
Sir A. Geikie, K.C.B., O.M., F.R.S.
Sir W. Crookes, O.M., Pres.R.S.
Sir W. Turner, K.C.B., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir James Dewar, LL.D., F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, D.C.L., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.
Sir Francis Darwin, F.R.S.
Sir J. J. Thomson, O.M., F.R.S.
Prof. T. G. Bonney, Sc.D., F.R.S.
Sir W. Ramsay, K.C.B., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.
Sir Oliver Lodge, D.Sc., F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

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A. Vernon Harcourt, D.C.L., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.
Major P. A. MacMahon, F.R.S.

AUDITORS.

Sir Edward Brabrook, C.B.
Professor H. McLeod, LL.D., F.R.S.

RULES OF
THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester*, 1907, *with subsequent amendments.*]

Chapter I.

Objects and Constitution.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress. Objects.

The Association contemplates no invasion of the ground occupied by other Institutions.

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members. Constitution.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association. Annual Meetings.

Chapter II.

The General Committee.

1. The General Committee shall be constituted of the following persons:— Constitution.

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members* –

(*a*) Vice-Presidents and Secretaries of the Sections.
(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(*c*) Delegates nominated by the Affiliated Societies.
(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission. 2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings. 3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions. 4. The General Committee shall

(i) Receive and consider the Report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the Report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer, and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the Officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

1. * The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the Chairman of the Conference of Delegates, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years. Constitution.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted. Functions.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting. Procedure.

* Amended by the General Committee at Winnipeg, 1909.

Chapter IV.

Research Committees.

Procedure.

1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

Constitution.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required.

GRANTS. (*a*) Drawn by Chairman.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants.

(*b*) Expire on June 30.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its Report is presented, due reason being given for such application.*

(*c*) Accounts and balance in hand

When application is made for a Committee to be re-appointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

(*d*) Additional Grant.

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members.

(*e*) *Caveat.*

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Disposal of specimens, apparatus, &c.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

* Amended by the General Committee at Dundee, 1912.

CHAPTER V.

The Council.

Constitution. 1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association. Elections.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two Members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five Members at least require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

CHAPTER VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an interim statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee. Audit.

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. Expenditure.

4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. Cheques.

Chapter VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees.

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

CHAPTER IX.

The Work of the Sections.

THE SECTIONS.

1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms.

3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

SECTIONAL COMMITTEES.

4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution.

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Privilege of Old Members.

(*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation.

(*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee; and they shall report such action to the Sectional Committee at its next meeting. EXECUTIVE FUNCTIONS

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise. Of President

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee. and of Recorder.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting. Organising Committee.

Each Organising Committee shall hold such meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section. Sectional Committee.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes. Papers and Reports.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations. It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed ; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required : to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication. 7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright. 8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors ; and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

Admission of Members and Associates.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. Applications.

* Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued. Obligations.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next Meeting.

2. All Members are eligible to any office in the Association. Conditions and Privileges of Membership.

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

* Amended by the General Committee at Dublin, 1908.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound.

Corresponding Members. 3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions. 4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report. 5. The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price; and Associates for a year shall be entitled to purchase, at the same price, the volume for that year.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Corresponding Societies are constituted as follows:

AFFILIATED SOCIETIES. 1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

ASSOCIATED SOCIETIES. (ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society. Applications.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable. CORRESPONDING SOCIETIES COMMITTEE.

Procedure.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee.

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association.

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairman, and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference. CONFERENCE OF DELEGATES.

Procedure and Functions.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during

each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations.

Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

TRUSTEES, GENERAL OFFICERS, &c., 1831–1914.

TRUSTEES.

1832–70 (Sir) R. I. MURCHISON (Bart.), F.R.S.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1832–39 C. BABBAGE, Esq., F.R.S.
1839–44 F. BAILY, Esq., F.R.S.
1844–58 Rev. G. PEACOCK, F.R.S.
1858–82 General E. SABINE, F.R.S.
1862–81 Sir P. EGERTON, Bart., F.R.S.
1872–1913 Sir J. LUBBOCK, Bart. (afterwards Lord AVEBURY), F.R.S.
1881–83 W. SPOTTISWOODE, Esq., Pres. R.S.
1883– Lord RAYLEIGH, F.R.S.
1883–98 Sir LYON (afterwards Lord) PLAYFAIR, F.R.S.
1898– Prof. (Sir) A. W. RÜCKER, F.R.S.
1913– Major P. A. MACMAHON, F.R.S.

GENERAL TREASURERS.

1831 JONATHAN GRAY, Esq.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1862–74 W. SPOTTISWOODE, Esq., F.R.S.
1874–91 Prof. A. W. WILLIAMSON, F.R.S.
1891–98 Prof. (Sir) A. W. RÜCKER, F.R.S.
1898–1904 Prof. G. C. FOSTER, F.R.S.
1904– Prof. JOHN PERRY, F.R.S.

GENERAL SECRETARIES.

1832–35 Rev. W. VERNON HARCOURT, F.R.S.
1835–36 Rev. W. VERNON HARCOURT, F.R.S., and F. BAILY, Esq., F.R.S.
1836–37 Rev. W. VERNON HARCOURT, F.R.S., and R. I. MURCHISON, Esq., F.R.S.
1837–39 R. I. MURCHISON, Esq., F.R.S., and Rev. G. PEACOCK, F.R.S.
1839–45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
1859–61 Prof. R. WALKER, F.R.S.
1861–62 W. HOPKINS, Esq., F.R.S.
1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
1866–68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868–71 Dr. T. A. HIRST, F.R.S., and Dr. T. THOMSON, F.R.S.
1871–72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872–76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900–02 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.
1902–03 Dr. D. H. SCOTT, F.R.S., and Major P. A. MACMAHON, F.R.S.
1903–13 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.
1913– Prof. W. A. HERDMAN, F.R.S., and Prof. H. H. TURNER, F.R.S.

ASSISTANT GENERAL SECRETARIES, &c.: 1831–1904.

1831 JOHN PHILLIPS, Esq., *Secretary.*
1832 Prof. J. D. FORBES, *Acting Secretary.*
1832–62 Prof. JOHN PHILLIPS, F.R.S.
1862–78 G. GRIFFITH, Esq., M.A.
1881 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary.*
1890 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1890–1902 G. GRIFFITH, Esq., M.A.
1902–04 J. G. GARSON, Esq., M.D.

ASSISTANT SECRETARIES.

1878–80 J. E. H. GORDON, Esq., B.A.
1904–09 A. SILVA WHITE, Esq.
1909– O. J. R. HOWARTH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association, 1901–1913.

(The List of Sectional Officers for 1914 will be found on p. xlvi.)

SECTION A.[1]—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1901. Glasgow ...	Major P. A. MacMahon, F.R.S.—*Dep. of Astronomy*, Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees (*Rec.*), W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast......	Prof. J. Purser, LL.D., M.R.I.A.—*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees (*Rec.*), Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees (*Rec.*), J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees (*Rec.*), Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. SouthAfrica	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr. C. H. Lees (*Rec.*).
1906. York.........	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter (*Rec.*), H. Dennis Taylor.
1907. Leicester...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter (*Rec.*).
1908. Dublin	Dr. W. N. Shaw, F.R.S.	Dr. W. G. Duffield, Dr. L. N. G. Filon, E. Gold, Prof. J. A. McClelland, Prof. A. W. Porter (*Rec.*), Prof. E. T. Whittaker.
1909. Winnipeg	Prof. E. Rutherford, F.R.S....	Prof. F. Allen, Prof. J. C. Fields, E. Gold, F. Horton, Prof. A. W. Porter (*Rec.*), Dr. A. A. Rambaut.
1910. Sheffield ...	Prof. E. W. Hobson, F.R.S....	H. Bateman, A. S. Eddington, E. Gold, Dr. F. Horton, Dr. S. R. Milner, Prof. A. W. Porter (*Rec.*).
1911. Portsmouth	Prof. H. H. Turner, F.R.S. ...	H. Bateman, Prof. P. V. Bevan, A. S. Eddington, E. Gold, Prof. A. W. Porter (*Rec.*), P. A. Yapp.
1912. Dundee ...	Prof. H. L. Callendar, F.R.S.	Prof. P. V. Bevan, E. Gold, Dr. H. B. Heywood, R. Norrie, Prof. A. W. Porter (*Rec.*), W. G. Robson, F. J. M. Stratton.
1913. Birmingham	Dr. H. F. Baker, F.R.S.	Prof. P. V. Bevan (*Rec.*), Prof. A. S. Eddington, E. Gold, Dr. H. B. Heywood, Dr. A. O. Rankine, Dr. G. A. Shakespear.

[1] Section A was constituted under this title in 1835, when the sectional division was introduced. The previous division was into 'Committees of Sciences.'

SECTION B.[2]—CHEMISTRY.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose (*Rec.*).
1902. Belfast......	Prof. E. Divers, F.R.S.........	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope (*Rec.*).
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope (*Rec.*).
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope (*Rec.*).
1905. SouthAfrica	George T. Beilby	W. A. Caldecott, Mr. M. O. Forster, Prof. G. G. Henderson (*Rec.*), C. F. Juritz.
1906. York.........	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope (*Rec.*).
1907. Leicester ...	Prof. A. Smithells, F.R.S. ...	Dr. E. F. Armstrong, Prof. A. W. Crossley (*Rec.*), J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F.R.S....	Dr. E. F. Armstrong (*Rec.*), Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J. H. Pollock.
1909. Winnipeg...	Prof. H. E. Armstrong, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, J. W. Shipley.
1910. Sheffield ...	J. E. Stead, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, W. E. S. Turner.
	Sub-section of Agriculture—A. D. Hall, F.R.S.	Dr. C. Crowther, J. Golding, Dr. E. J. Russell.
1911. Portsmouth	Prof. J. Walker, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. T. M. Lowry, Dr. F. Beddow.
1912. Dundee ...	Prof. A. Senier, M.D.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. J. K. Wood.
1913. Birmingham	Prof. W. P. Wynne, F.R.S....	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. H. McCombie.

SECTION C.[3]—GEOLOGY.

1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*).
1902. Belfast......	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*), J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton (*Rec.*).

[2] 'Chemistry and Mineralogy,' 1835–1894.
[3] 'Geology and Geography,' 1835–1850.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman (*Rec.*), J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.........	G. W. Lamplugh, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester...	Prof. J. W. Gregory, F.R.S....	Dr. F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas (*Rec.*)
1908. Dublin......	Prof. John Joly, F.R.S.	Rev. W. L. Carter, J. Lomas (*Rec.*), Prof. S. H. Reynolds, H. J. Seymour.
1909. Winnipeg...	Dr. A. Smith Woodward, F.R.S.	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, R. T. Hodgson, Prof. S. H. Reynolds.
1910. Sheffield ...	Prof. A. P. Coleman, F.R.S...	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, B. Hobson, Prof. S. H. Reynolds.
1911. Portsmouth	A. Harker, F.R.S.	Col. C. W. Bevis, W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, Prof. S. H. Reynolds.
1912. Dundee ...	Dr. B. N. Peach, F.R.S.	Prof. W. B. Boulton, A. W. R. Don, Dr. A. R. Dwerryhouse (*Rec.*), Prof. S. H. Reynolds.
1913. Birmingham	Prof. E. J. Garwood, M.A. ...	Prof. W. S. Boulton, Dr. A. R. Dwerryhouse (*Rec.*), F. Raw, Prof. S. H. Reynolds.

SECTION D.[1]—ZOOLOGY.

1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr (*Rec.*), J. Rankin, J. Y. Simpson.
1902. Belfast......	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson (*Rec.*).
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1905. SouthAfrica	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Dr. H. W. M. Tims, Prof. J. Y. Simpson (*Rec.*).
1906. York.........	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims (*Rec.*).
1907. Leicester...	Dr. W. E. Hoyle, M.A.........	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims (*Rec.*).
1908. Dublin......	Dr. S. F. Harmer, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims (*Rec.*).
1909. Winnipeg...	Dr. A. E. Shipley, F.R.S. ...	C. A. Baragar, C. L. Boulenger, Dr. J. Pearson, Dr. H. W. M. Tims (*Rec.*).

[1] 'Zoology and Botany,' 1835–1847; 'Zoology and Botany, including Physiology,' 1848–1865; 'Biology,' 1866–1894.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1910. Sheffield ...	Prof. G. C. Bourne, F.R.S. ...	Dr. J. H. Ashworth, L. Doncaster, T. J. Evans, Dr. H. W. M. Tims (*Rec.*).
1911. Portsmouth	Prof. D'Arcy W. Thompson, C.B.	Dr. J. H. Ashworth, C. Foran, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).
1912. Dundee ...	Dr. P. Chalmers Mitchell, F.R.S.	Dr. J. H. Ashworth, R. D. Laurie, Miss D. L. Mackinnon, Dr. H. W. M. Tims (*Rec.*).
1913. Birmingham	Dr. H. F. Gadow, F.R.S......	Dr. J. H. Ashworth, Dr. C. L. Boulenger, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).

SECTION E.[5]—GEOGRAPHY.

1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson (*Rec.*), E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast......	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm (*Rec.*), E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport...	Capt. E. W. Creak, R.N., C.B., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.........	E. Heawood (*Rec.*), Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. SouthAfrica	Adm. Sir W. J. L. Wharton, R.N., K.C.B., F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson (*Rec.*), H. Y. Oldham.
1906. York.	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.
1907. Leicester ...	George G. Chisholm, M.A. ...	E. Heawood (*Rec.*), O. J. R. Howarth, E. A. Reeves, T. Walker.
1908. Dublin......	Major E. H. Hills, C.M.G., R.E.	W. F. Bailey, W. J. Barton, O. J. R. Howarth (*Rec.*), E. A. Reeves.
1909. Winnipeg...	Col. Sir D. Johnston, K.C.M.G., C.B., R.E.	G. G. Chisholm (*Rec.*), J. McFarlane, A. McIntyre.
1910. Sheffield ...	Prof. A. J. Herbertson, M.A., Ph.D.	Rev. W. J. Barton (*Rec.*), Dr. R. Brown, J. McFarlane, E. A. Reeves.
1911. Portsmouth	Col. C. F. Close, R.E., C.M.G.	J. McFarlane (*Rec.*), E. A. Reeves, W. P. Smith.
1912. Dundee ...	Col. Sir C. M. Watson, K.C.M.G.	Rev. W. J. Barton (*Rec.*), J. McFarlane, E. A. Reeves, D. Wylie.
1913. Birmingham	Prof. H. N. Dickson, D.Sc. ...	Rev. W. J. Barton (*Rec.*), P. E. Martineau, J. McFarlane, E. A. Reeves.

SECTION F.[6]—ECONOMIC SCIENCE AND STATISTICS.

1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan (*Rec.*), S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. A. Duffin.

[5] Section E was that of 'Anatomy and Medicine,' 1835–1840; of 'Physiology' (afterwards incorporated in Section D), 1841–1847. It was assigned to 'Geography and Ethnology,' 1851–1868; 'Geography,' 1869.

[6] 'Statistics,' 1835–1855.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1903 Southport	E. W. Brabrook, C.B.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley (*Rec.*), Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.........	A. L. Bowley, M.A.	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester ...	Prof. W. J. Ashley, M.A.......	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin......	W. M. Acworth, M.A.	W. G. S. Adams, Prof. S. J. Chapman (*Rec.*), Prof. D. H. Macgregor, H. O. Meredith.
	Sub-section of Agriculture—Rt. Hon. Sir H. Plunkett.	A. D. Hall, Prof. J. Percival, J. H. Priestley, Prof. J. Wilson.
1909. Winnipeg...	Prof. S. J. Chapman, M.A. ...	Prof. A. B. Clark, Dr. W. A. Manahan, Dr. W. R. Scott (*Rec.*).
1910. Sheffield ...	Sir H. Llewellyn Smith, K.C.B., M.A.	C. R. Fay, H. O. Meredith (*Rec.*), Dr. W. R. Scott, R. Wilson.
1911. Portsmouth	Hon. W. Pember Reeves	C. R. Fay, Dr. W. R. Scott (*Rec.*), H. A. Stibbs.
1912. Dundee ...	Sir H. H. Cunynghame, K.C.B.	C. R. Fay, Dr. W. R. Scott (*Rec.*), E. Tosh.
1913. Birmingham	Rev. P. H. Wicksteed, M.A.	C. R. Fay, Prof. A. W. Kirkaldy, Prof. H. O. Meredith, Dr. W. R. Scott (*Rec.*).

SECTION G.[7]—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price (*Rec.*).
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price (*Rec.*), J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price (*Rec.*).
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price (*Rec.*).
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall (*Rec.*), Prof. H. Payne, E. Williams.
1906. York.........	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price (*Rec.*), J. Triffit.
1907. Leicester...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price (*Rec.*), H. E. Wimperis.
1908. Dublin......	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price (*Rec.*), H. E. Wimperis.
1909. Winnipeg...	Sir W. H. White, K.C.B., F.R.S.	E. E. Brydone-Jack, Prof. E. G. Coker, Prof. E. W. Marchant, W. A. Price (*Rec.*).
1910. Sheffield ..	Prof. W. E. Dalby, M.A., M.Inst.C.E.	F. Boulden, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.
1911. Portsmouth	Prof. J. H. Biles, LL.D., D.Sc.	H. Ashley, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.

[7] 'Mechanical Science,' 1836-1900.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1912. Dundee ...	Prof. A. Barr, D.Sc.	Prof. E. G. Coker (*Rec.*), A. R. Fulton, H. Richardson, A. A. Rowse, H. E. Wimperis.
1913. Birmingham	Prof. Gisbert Kapp, D.Eng....	Prof. E. G. Coker (*Rec.*), J. Purser, A. A. Rowse, H. E. Wimperis.

SECTION H.[8]—ANTHROPOLOGY.

1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres (*Rec.*).
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon J. L. Myres (*Rec.*).
1903. Southport...	Prof. J. Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres (*Rec.*).
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres (*Rec.*).
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland (*Rec.*).
1906. York.........	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ..	D. G. Hogarth, M.A............	C. J. Billson, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.
1909. Winnipeg...	Prof. J. L. Myres, M.A.	H. S. Kingsford (*Rec.*), Prof. C. J. Patten, Dr. F. C. Shrubsall.
1910. Sheffield ...	W. Crooke, B.A.	E. N. Fallaize (*Rec.*), H. S. Kingsford, Prof. C. J. Patten, Dr. F. C. Shrubsall.
1911. Portsmouth	W. H. R. Rivers, M.D., F.R.S.	E. N. Fallaize (*Rec.*), H. S. Kingsford, E. W. Martindell, H. Rundle, Dr. F. C. Shrubsall.
1912. Dundee ...	Prof. G. Elliot Smith, F.R.S.	D. D. Craig, E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall.
1913. Birmingham	Sir Richard Temple, Bart. ...	E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall, T. Yeates.

SECTION I.[9]—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY).

1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson (*Rec.*).
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne (*Rec.*), Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft (*Rec.*), Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft (*Rec.*), Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.

[8] Established 1884. [9] Established 1894.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1906. York.........	Prof. F. Gotch, F.R.S.	J. Barcroft (*Rec.*), Dr. J. M. Hamill, Prof. J. S. Macdonald, Dr. D. S. Long.
1907. Leicester...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft (*Rec.*), Prof. J. S. Macdonald, Dr. A. Warner.
1908. Dublin......	Dr. J. Scott Haldane, F.R.S.	Prof. D. J. Coffey, Dr. P. T. Herring, Prof. J. S. Macdonald, Dr. H. E. Roaf (*Rec.*).
1909. Winnipeg...	Prof. E. H. Starling, F.R.S....	Dr. N. H. Alcock (*Rec.*), Prof. P. T. Herring, Dr. W. Webster.
1910. Sheffield ...	Prof. A. B. Macallum, F.R.S.	Dr. H. G. M. Henry, Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1911. Portsmouth	Prof. J. S. Macdonald, B.A.	Dr. J. T. Leon, Dr. Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1912. Dundee ...	Leonard Hill, F.R.S.	Dr. Keith Lucas, W. Moodie, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1913. Birmingham	Dr. F. Gowland Hopkins, F.R.S.	C. L. Burt, Prof. P. T. Herring, Dr. T. G. Maitland, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.

SECTION K.[10]—BOTANY.

1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward (*Rec.*), H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager (*Rec.*), R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager (*Rec.*), R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S. ...... *Sub-section of Agriculture*—Dr. W. Somerville.	Dr. F. F. Blackman, A. G. Tansley, H. Wager (*Rec.*), T. B. Wood, R. H. Yapp.
1905. South Africa	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp (*Rec.*).
1906. York.........	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1907. Leicester...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1908. Dublin......	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1909. Winnipeg...	Lieut.-Col. D. Prain, C.I.E., F.R.S. *Sub-section of Agriculture*—Major P. G. Craigie, C.B.	Prof. A. H. R. Buller, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*). W. J. Black, Dr. E. J. Russell, Prof. J. Wilson.
1910. Sheffield ...	Prof. J. W. H. Trail, F.R.S	B. H. Bentley, R. P. Gregory, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*).
1911. Portsmouth	Prof. F. E. Weiss, D.Sc. ...... *Sub-section of Agriculture*—W. Bateson, M.A., F.R.S.	C. G. Delahunt, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, Prof. R. H. Yapp (*Rec.*). J. Golding, H. R. Pink, Dr. E. J. Russell.

[10] Established 1895.

Date and Place	Presidents	Secretaries (*Rec.* Recorder)
1912. Dundee ...	Prof. F. Keeble, D.Sc.	J. Brebner, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.
1913. Birmingham	Miss Ethel Sargant, F.L.S....	W. B. Grove, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers (*Rec.*).
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport ..	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller (*Rec.*), Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins (*Rec.*), J. R. Whitton.
1906. York.........	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Hugh Richardson.
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory (*Rec.*), J. S. Laver, Hugh Richardson.
1908. Dublin	Prof. L. C. Miall, F.R.S.	Prof. E. P. Culverwell, W. D. Eggar, George Fletcher, Prof. R. A. Gregory (*Rec.*), Hugh Richardson.
1909. Winnipeg...	Rev. H. B. Gray, D.D.	W. D. Eggar, R. Fletcher, J. L. Holland (*Rec.*), Hugh Richardson.
1910. Sheffield ...	Principal H. A. Miers, F.R.S.	A. J. Arnold, W. D. Eggar, J. L. Holland (*Rec.*), Hugh Richardson.
1911. Portsmouth	Rt. Rev. J. E. C. Welldon, D.D.	W. D. Eggar, O. Freeman, J. L. Holland (*Rec.*), Hugh Richardson.
1912. Dundee ...	Prof. J. Adams, M.A.	D. Berridge, Dr. J. Davidson, Prof. J. A. Green (*Rec.*), Hugh Richardson.
1913. Birmingham	Principal E. H. Griffiths, F.R.S.	D. Berridge, Rev. S. Blofeld, Prof. J. A. Green (*Rec.*), H. Richardson.

SECTION M.—AGRICULTURE.

1912. Dundee ...	T. H. Middleton, M.A..........	Dr. C. Crowther, J. Golding, Dr. A. Lauder, Dr. E. J. Russell (*Rec.*).
1913. Birmingham	Prof. T. B. Wood, M.A.	W. E. Collinge, Dr. C. Crowther, J. Golding, Dr. E. J. Russell (*Rec.*).

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES, 1901-11.[1]

Date and Place	Chairmen	Secretaries
1901. Glasgow ...	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902 Belfast......	Prof. W. W. Watts, F.G.S. ...	E. J. Bles.
1903. Southport ..	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London ...	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York.........	Sir Edward Brabrook, C.B....	F. W. Rudler.
1907. Leicester ...	H. J. Mackinder, M.A.........	F. W. Rudler, I.S.O.
1908. Dublin	Prof. H. A. Miers, F.R.S.......	W. P. D. Stebbing.
1909. London ...	Dr. A. C. Haddon, F.R.S. ...	W. P. D. Stebbing.
1910. Sheffield ...	Dr. Tempest Anderson.........	W. P. D. Stebbing.
1911. Portsmouth	Prof. J. W. Gregory, F.R.S....	W. P. D. Stebbing.
1912. Dundee ...	Prof. F. O. Bower, F.R.S. ...	W. P. D. Stebbing.
1913. Birmingham	Dr. P. Chalmers Mitchell, F.R.S.	W. P. D. Stebbing.
1914. Le Havre...	Sir H. George Fordham ...	W. Mark Webb.

EVENING DISCOURSES, 1901-1914.

Date and Place	Lecturer	Subject of Discourse
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	Francis Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.
1903. Southport...	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. South Africa:		
Cape Town ...	Prof. E. B. Poulton, F.R.S....	W. J. Burchell's Discoveries in South Africa.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban ...	Douglas W. Freshfield.........	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritzburg.	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S. ...	The Distribution of Power.
	Prof. J. O. Arnold..............	Steel as an Igneous Rock.
Pretoria ...	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein...	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley ...	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo ...	D. Randall-MacIver	The Ruins of Rhodesia.

[1] Established 1885.

Date and Place	Lecturer	Subject of Discourse
1906. York........	Dr. Tempest Anderson........	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.
1907. Leicester ...	W. Duddell, F.R.S.	The Ark and the Spark in Radio-telegraphy.
	Dr. F. A. Dixey.................	Recent Developments in the Theory of Mimicry.
1908. Dublin	Prof. H. H. Turner, F.R.S. ...	Halley's Comet.
	Prof. W. M. Davis	The Lessons of the Colorado Canyon.
1909. Winnipeg...	Dr. A. E. H. Tutton, F.R.S....	The Seven Styles of Crystal Architecture.
	Prof. W. A. Herdman, F.R.S.	Our Food from the Waters.
	[1] Prof. H. B. Dixon, F.R.S....	The Chemistry of Flame.
	[1] Prof. J. H. Poynting, F.R.S.	The Pressure of Light.
1910. Sheffield ...	Prof. W. Stirling, M.D.	Types of Animal Movement.[2]
	D. G. Hogarth	New Discoveries about the Hittites.
1911. Portsmouth	Dr. Leonard Hill, F.R.S......	The Physiology of Submarine Work.
	Prof. A. C. Seward, F.R.S. ...	Links with the Past in the Plant World.
1912. Dundee ...	Prof. W. H. Bragg, F.R.S. ...	Radiations Old and New.
	Prof. A. Keith, M.D............	The Antiquity of Man.
1913. Birmingham	Sir H. H. Cunynghame, K.C.B.	Explosions in Mines and the Means of Preventing them.
	Dr. A. Smith Woodward, F.R.S.	Missing Links among Extinct Animals.
1914. Australia:		
Adelaide	Sir Oliver J. Lodge, F.R.S....	The Ether of Space.
	Prof. W. J. Sollas, F.R.S. ...	Ancient Hunters.
Melbourne	Prof. E. B. Poulton, F.R.S ...	Mimicry.
	Dr. F. W. Dyson, F.R.S. ...	Greenwich Observatory.
Sydney ...	Prof. G. Elliot Smith, F.R.S.	Primitive Man.
	Sir E. Rutherford, F.R.S. ...	Atoms and Electrons.
Brisbane	Prof. H. E. Armstrong, F.R.S.	The Materials of Life.
	Prof. G. W. O. Howe	Wireless Telegraphy.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Lecture
1901. Glasgow ...	H. J. Mackinder, M.A..........	The Movements of Men by Land and Sea.
1902. Belfast......	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport...	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge..	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.
1906. York........	Prof. S. P. Thompson, F.R.S.	The Manufacture of Light.
1907. Leicester ...	Prof. H. A. Miers, F.R.S.......	The Growth of a Crystal.
1908. Dublin	Dr. A. E. H. Tutton, F.R.S.	The Crystallisation of Water.
1910. Sheffield ...	C. T. Heycock, F.R.S.	Metallic Alloys.
1911. Portsmouth	Dr. H. R. Mill	Rain.

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg.
[2] Repeated, to the public, on Wednesday, September 7.

PUBLIC OR CITIZENS' LECTURES.

Date and Place	Lecturer	Subject of Lecture
1912. Dundee ...	Prof. B. Moore, D.Sc.	Science and National Health.
	Prof. E. C. K. Gonner, M.A.	Prices and Wages.
	Prof. A. Fowler, F.R.S.	The Sun.
1913. Birmingham	Dr. A. C. Haddon, F.R.S. ...	The Decorative Art of Savages.
	Dr. Vaughan Cornish	The Panama Canal.
	Leonard Doncaster, M.A. ...	Recent Work on Heredity and its Application to Man.
	Dr. W. Rosenhain, F.R.S. ...	Metals under the Microscope.
	Frederick Soddy, F.R.S.	The Evolution of Matter.
1914. Australia:		
Perth ...	Prof. W. A. Herdman, F.R.S.	Why we Investigate the Ocean.
	Prof. A. S. Eddington, F.R.S.	Stars and their Movements.
	H. Balfour, M.A.	Primitive Methods of Making Fire.
	Prof. A. D. Waller, F.R.S. ...	Electrical Action of the Human Heart.
	C. A. Buckmaster, M.A.	Mining Education in England.
Adelaide	Prof. E. C. K. Gonner, M.A.	Saving and Spending.
Melbourne	Dr. W. Rosenhain, F.R.S. ...	Making of a Big Gun.
	Prof. H. B. Dixon, F.R.S. ...	Explosions.
Sydney ...	Prof. B. Moore, F.R.S.........	Brown Earth and Bright Sunshine.
	Prof. H. H. Turner, P.R.S. ...	Comets.
Brisbane	Dr. A. C. Haddon, F.R.S. ...	Decorative Art in Papua.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes, 1901-1913.

1901.

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean	50	0	0
Compound Ascidians of the Clyde Area	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903.

	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves	40	0	0
Underground Waters of North-west Yorkshire	40	0	0

	£	s.	d.
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Committee	20	0	0
	£845	13	2

1904.

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	18	11

1905.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitroamines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s.	d.
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitroamines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907.

	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7
Anthropometric Investigations in the British Isles	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research on South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.

	£	s.	d.
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitroamines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0

	£	s.	d.
Exploration in Spitsbergen	30	0	0
Gold Coinage in Circulation in the United Kingdom	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues	40	0	0
The Ductless Glands	13	14	8
Effect of Climate upon Health and Disease	35	0	0
Body Metabolism in Cancer	30	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1,157	18	8

1909.

	£	s.	d.
Seismological Observations	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism	35	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants	5	0	0
Botanical Photographs	10	0	0
Experimental Study of Heredity	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1,014	9	9

1910.

	£	s.	d.
Measurement of Geodetic Arc in South Africa	100	0	0
Republication of Electrical Standards Reports	100	0	0
Seismological Observations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	35	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
South African Strata	5	0	0
Fossils of Midland Coalfields	25	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Heredity Experiments	15	0	0
Feeding Habits of British Birds	5	0	0
Amount and Distribution of Income	15	0	0
Gaseous Explosions	75	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Excavations on Roman Sites in Britain	5	0	0
Neolithic Sites in Northern Greece	5	0	0
The Ductless Glands	40	0	0
Body Metabolism in Cancer	20	0	0
Anæsthetics	25	0	0
Tissue Metabolism	25	0	0
Mental and Muscular Fatigue	18	17	0
Electromotive Phenomena in Plants	10	0	0

	£	s.	d.
Structure of Fossil Plants ...	10	0	0
Experimental Study of Heredity	30	0	0
Survey of Clare Island	30	0	0
Corresponding Societies Committee	20	0	0
	£963	17	0

1911.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	15	0	0
Influence of Carbon, &c., on Corrosion of Steel	15	0	0
Crystalline Rocks of Anglesey	2	0	0
Mammalian Fauna in Miocene Deposits, Bugti Hills, Baluchistan	75	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Feeding Habits of British Birds	5	0	0
Belmullet Whaling Station	30	0	0
Map of Prince Charles Foreland	30	0	0
Gaseous Explosions	90	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Age of Stone Circles	30	0	0
Artificial Islands in Highland Lochs	10	0	0
The Ductless Glands	40	0	0
Anæsthetics	20	0	0
Mental and Muscular Fatigue	25	0	0
Electromotive Phenomena in Plants	10	0	0
Dissociation of Oxy-Hæmoglobin	25	0	0
Structure of Fossil Plants ...	15	0	0
Experimental Study of Heredity	45	0	0
Survey of Clare Island	20	0	0
Registration of Botanical Photographs	10	0	0
Mental and Physical Factors involved in Education	10	0	0
Corresponding Societies Committee	20	0	0
	£922	0	0

1912.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	30	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Further Tabulation of Bessel Functions	15	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	10	0	0
Study of Plant Enzymes	30	0	0
Erratic Blocks	5	0	0
Igneous and Associated Rocks of Glensaul, &c.	15	0	0
List of Characteristic Fossils	5	0	0
Sutton Bone Bed	15	0	0
Bembridge Limestone at Creechbarrow Hill	20	0	0
Table at the Zoological Station at Naples	50	0	0
Index Animalium	75	0	0
Belmullet Whaling Station	20	0	0
Secondary Sexual Characters in Birds	10	0	0
Gaseous Explosions	60	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Artificial Islands in Highland Lochs	10	0	0
Physical Character of Ancient Egyptians	40	0	0
Excavation in Easter Island	15	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure of Fossil Plants ...	15	0	0
Experimental Study of Heredity	35	0	0
Survey of Clare Island	20	0	0
Jurassic Flora of Yorkshire	15	0	0
Overlapping between Secondary and Higher Education	1	18	6
Curricula, &c., of Industrial and Poor Law Schools	10	0	0
Influence of School Books upon Eyesight	3	9	0
Corresponding Societies Committee	25	0	0
Collections illustrating Natural History of Isle of Wight	40	0	0
	£845	7	6

1913.

	£	s.	d.
Seismological Investigations	130	0	0
Investigation of the Upper Atmosphere	25	0	0
International Committee on Physical and Chemical Constants	40	0	0
Calculation of Mathematical Tables	20	0	0
Disposal of Copies of the 'Binary Canon'	4	9	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Study of Plant Enzymes	25	0	0
Correlation of Crystalline Form with Molecular Structure	25	0	0
Study of Solubility Phenomena	10	0	0
List of Characteristic Fossils	5	0	0
Geology of Ramsey Island	10	0	0
Fauna and Flora of Trias of Western Midlands	10	0	0
Critical Sections in Lower Palæozoic Rocks	15	0	0
Belmullet Whaling Station	20	0	0
Nomenclature Animalium Genera et Sub-genera	50	0	0
Antarctic Whaling Industry	75	0	0
Maps for School and University Use	40	0	0
Gaseous Explosions	50	0	0
Stress Distributions in Engineering Materials	50	0	0
Lake Villages in the Neighbourhood of Glastonbury	20	0	0
Age of Stone Circles	20	0	0
Artificial Islands in the Highlands of Scotland	5	0	0
Excavations on Roman Sites in Britain	20	0	0
Anthropometric Investigations in Cyprus	50	0	0
Palæolithic Site in Jersey	50	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure and Function of the Mammalian Heart	30	0	0
Binocular Combination of Kinematograph Pictures	0	17	0
Structure of Fossil Plants	15	0	0
Jurassic Flora of Yorkshire	5	0	0
Flora of the Peat of the Kennet Valley	15	0	0
Vegetation of Ditcham Park	14	4	3
Physiology of Heredity	30	0	0
Breeding Experiments with Œnotheras	19	17	4
Mental and Physical Factors involved in Education	20	0	0
Influence of School Books on Eyesight	2	8	9
Character, Work, and Maintenance of Museums	10	0	0
Corresponding Societies Committee	25	0	0
	£1,086	16	4

REPORT OF THE COUNCIL, 1913-14.

I. The Council have to record their profound sorrow at the death of Sir David Gill, F.R.S., ex-President. The following resolution was conveyed to Lady Gill by the President:—

'The Council deeply regret the death of their late distinguished President, Sir David Gill, whose personality was so widely appreciated, and whose work for Astronomy at the Cape Observatory elevated it to the first rank; and they empower the Officers to convey to Lady Gill and his family their profound sympathy.'

II. Professor A. Schuster, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for 1915-16 (Manchester Meeting).

III. Caird Fund.—(*a*) Resolutions referred by the General Committee to the Council for consideration and, if desirable, for action, were dealt with as follows:—

(1) 'That the Council be asked to appoint a Committee to carry out the request of Sir J. K. Caird in his letter of September 10 (viz., that his further gift of £1,000 be earmarked for the study of Radio-Activity as a branch of Geo-Physics).'

It was resolved to appoint the following Committee to carry out the above request: The President and General Officers, Sir E. Rutherford, Mr. F. Soddy, and Sir J. J. Thomson. The Committee was empowered to add to its number and to modify the condition attaching to the above gift, subject to the approval of Sir J. K. Caird.

(2) 'That the request of Section A (Mathematics and Physics) for a grant from the Caird Fund of £500 for Radio-telegraphic investigations be sent to the Council for consideration and action.'

It was resolved that the above request be granted, and that the General Treasurer be empowered to pay the sum named to the Chairman of the Committee appointed to conduct the said investigations.

(3) 'That a grant of £100 for the coming year be made to the Committee on the Naples Table from the Caird Fund, and that the Council be requested to consider the advisability of endowing the Committee by a capital sum yielding an annual income of £100.'

It was resolved that a grant of £100 for the coming year be made to the Committee on the Naples Table from the Caird Fund, and that a grant of £100 be made annually in future to the Committee, subject to the adoption of its annual report.

(4) 'That a grant of £100 for the coming year be made to the Committee on Seismological Investigations from the Caird Fund, and that the Council be asked to consider the advisability of endowing the Committee by a capital sum yielding an annual income of £100.'

It was resolved that a grant of £100 for the coming year be made to the Committee on Seismological Investigations, and that a grant of £100 be made annually in future to the Committee, subject to the adoption of its annual report.

(*b*) An application to the Council from the 'Scotia' Publication Committee (Scottish Antarctic Expedition) for a grant of £400 from the Caird Fund towards the expenses of the publication of the 'Scientific Results of the Voyage of the "Scotia"' was considered, and it was resolved that the application could not be entertained.

IV. RESOLUTIONS referred to the Council by the General Committee at Birmingham for consideration, and, if desirable, for action, were dealt with as follows:—

From Sections A and E.

'That the terms First Order, Second Order, Third Order, and Fourth Order of triangulation, as connoting definite degrees of precision, be used to describe triangulation even though the terms now in use (*e.g.*, Major, Minor, &c.), which have only a local significance, are also employed.'

'That this resolution be communicated through the proper channels to (*a*) the Geodetic Association, and (*b*) the Institute of Surveyors.'

The Council approved the principle of the above resolution, and resolved that Professor H. H. Turner and Captain H. G. Lyons be appointed a Committee to communicate, in the name of the Council, with the Geodetic Association and the Institute of Surveyors. The Committee duly carried out this instruction.

From Section I.

'The Committee of Section I requests the Council of the Association to forward to the Board of Trade the following resolution:—

(i) That Colour Vision Tests are most efficiently conducted by means of what is known as the "Lantern Test."

(ii) That the best form of such lantern has not yet been finally decided upon, and can be arrived at only after further expert report.

(iii) That the actual application of sight tests requires the co-operation of an ophthalmic surgeon with a practical navigator.'

The Council, after careful consideration and consultation among members specially interested in this question, resolved to take no action.

From Section I.

'That in view of the fact that numerous deaths continue to take place from anæsthetics administered by unregistered persons, the Committee of the Section of Physiology of the British Association appeals to the Council of the Association to represent to the Home Office and to the Privy Council the urgent need of legislation to protect the public against such unnecessary risks.'

The Council appointed a Committee to consider and report upon the above resolution, and subsequently adopted the following resolution, which was transmitted to the Home Office:—

'The Council of the British Association desire to urge upon His Majesty's Government the necessity of introducing legislation on the subject of the administration of anæsthetics, as recommended by the Departmental Committee of the Home Office, dated March 18, 1910, but with the addition to Recommendation (3) of a clause permitting administration by unregistered persons under the immediate supervision of a person duly qualified. The Council would point out that the recommendations of the General Medical Council are practically identical with those of the Departmental Committee, and that these recommendations have been approved by various academic and professional bodies, and also by the Council of this Association in 1910.'

V. In connection with the Magnetic Re-survey of the British Isles, referred to in the Report of the Council for 1912-13, the Council agreed to the proposal of the Royal Society that a joint supervising committee of the Society and the Association be appointed, and the following members were appointed to represent the Association: Sir Oliver Lodge, Prof. J. Perry, Prof. H. H. Turner, Dr. C. Chree, Dr. S. Chapman, Dr. F. W. Dyson, Dr. R. T. Glazebrook.

The Council empowered the General Treasurer to pay from the Caird Fund a sum not exceeding £250 towards the cost of the Survey.

VI. Australian Meeting.—(i) At their meeting in December 1913 the Council were informed as to the limit of the total number of the oversea party which the Australian authorities had found it necessary to propose, having regard to the provision of suitable travelling facilities, &c., in Australia. The Council were also informed that by counting all doubtful or qualified intimations from members, and all applications for new membership, the limit above mentioned was already substantially exceeded. It was resolved (*a*) that there should be no more admissions to the oversea party, excepting any member whose attendance the Australian Committee or the General Officers (in consultation, if necessary, with representatives of any particular Section) might decide to be of special importance to the scientific work of the meeting; (*b*) that the General Secretaries should be empowered to desire members whose intimations were qualified by

doubt to express their definite intentions by a certain date; (c) that the General Officers should be empowered to take, in the name of the Council, any other measures which might appear necessary to effect a reduction in the total number of the oversea party.

(ii) Previously to the departure of Dr. A. C. D. Rivett, General Organising Secretary in Australia, from London in December 1913, it was resolved that the thanks of the Council be expressed to Dr. Rivett for the assistance he had rendered in connection with the arrangements for the meeting during his visit to England, and to the authorities in Australia under whose direction he had paid this visit.

VII. The Council resolved that the meetings of the Conference of Delegates of Corresponding Societies be held in Havre in August 1914 on the occasion of the meeting there of L'Association Française pour l'Avancement des Sciences.

In these circumstances the Council made the following appointments on behalf of the General Committee (in place of nominations, as usual):—

Conference of Delegates.—Sir H. G. Fordham (*Chairman*), Sir E. Brabrook (*Vice-Chairman*), Mr. W. Mark Webb (*Secretary*).

The following nominations are made by the Council:—

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W. Mark Webb (*Secretary*), Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.

VIII. The Council have received an intimation from the Town Clerk of Cardiff that the Council and other authorities in that city intend to present an invitation to the Association to hold there its Meeting in 1918.

IX. The Council have received reports from the General Treasurer during the past year. In consequence of the early removal of the books, &c., from London to Australia, it has not been possible to prepare the usual annual accounts. These will be audited and presented to the General Committee at the Manchester Meeting (1915).

X. The retiring members of the Council are:—

Sir D. Prain, Prof. C. S. Sherrington, Prof. F. T. Trouton, Dr. J. E. Marr, Prof. J. B. Farmer.

The Council nominated the following new members:—

Dr. F. W. Dyson,
Miss E. R. Saunders,
Prof. E. H. Starling,

leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of ordinary members is as follows:—

Prof. H. E. Armstrong.
Sir E. Brabrook.
Prof. W. H. Bragg.
Dr. Dugald Clerk.
Major P. G. Craigie.
W. Crooke.
Prof. A. Dendy.
Dr. F. A. Dixey.
Prof. H. B. Dixon.
Dr. F. W. Dyson.
Principal E. H. Griffiths.
Dr. A. C. Haddon.
A. D. Hall.
Prof. W. D. Halliburton.
Sir Everard im Thurn.
Alfred Lodge.
Capt. H. G. Lyons.
Prof. R. Meldola.
Prof. J. L. Myres.
Miss E. R. Saunders.
Prof. E. H. Starling
J. J. H. Teall.
Prof. S. P. Thompson.

XI. The General Officers have been nominated by the Council as follows:—

General Treasurer: Prof. J. Perry.
General Secretaries: Prof. W. A. Herdman.
Prof. H. H. Turner.

XII. The following have been admitted as members of the General Committee:—

Prof. H. S. Carslaw.
Prof. W. J. Dakin.
Prof. T. W. Edgeworth David.
Prof. W. G. Duffield.
Mr. A. du Toit.
Prof. A. J. Ewart.
Mr. J. T. Ewen.
Prof. H. J. Fleure.
Mr. Willoughby Gardner.
Prof. Kerr Grant.
Mr. C. Hedley.
Prof. W. A. Jolly.
Dr. C. F. Juritz.
Prof. T. Lyle.
Dr. H. McCombie.
Mr. J. H. Maiden.
Dr. R. R. Marett.
Prof. Orme Masson.
Dr. N. V. Sidgwick.
Prof. C. Michie Smith.
Prof. W. Baldwin Spencer.
Prof. B. D. Steele.
Prof. E. C. Stirling.
Dr. W. E. Sumpner.
Major A. J. N. Tremearne.

Dr. THE GENERAL TREASURER IN ACCOUNT ADVANCEMENT OF SCIENCE,

1913–1914. RECEIPTS.

	£	s.	d.	£	s.	d.
Balance brought forward				1,375	13	3
Life Compositions (including Transfers)				549	0	0
Annual Subscriptions				782	0	0
New Annual Members' Subscriptions				356	0	0
Sale of Associates' Tickets				1,266	0	0
Sale of Ladies' Tickets				290	0	0
Sale of Publications				248	2	0
Sir James Caird's Gift (Radio-activity Investigation)				1,000	0	0
Interest on Deposits:						
Lloyds Bank, Birmingham				52	0	10
Bank of Scotland, Dundee				2	16	11
Unexpended Balances of Grants returned:						
Fossil Plants	0	10	3			
Corresponding Societies Committee	1	14	8			
Jurassic Flora	3	14	1			
				5	19	0
Dividends on Investments:						
Consols	134	4	8			
India 3 per Cent. Stock	101	14	0			
Great Indian Peninsula Railway 'B' Annuity	29	1	6			
				265	0	2
Dividends on 'Caird Fund' Investments:						
London and North-Western Railway Consolidated 4 per Cent. Preference Stock	94	3	4			
London and South-Western Railway do. do.	94	3	4			
India 3½ per Cent. Stock	86	11	8			
Canada 3½ per Cent. Registered Stock	82	7	10			
				357	6	2
Australian Government Subsidy: 1914 Meeting				15,000	0	0

Mem.: Receipts on account of the Australian Meeting (1914), amounting to £243, are not included in this account, but are paid to a separate (No. 2) account at the Bank.

Investments.

Nominal Amount £	s.	d.		Value 30th June, 1914. £	s.	d.
5,701	10	5	2½ per Cent. Consolidated Stock	4,276	2	10
3,600	0	0	India 3 per Cent. Stock	2,700	0	0
879	14	9	£43 Great Indian Peninsula Railway 'B' Annuity (cost)	849	5	0
2,627	0	10	India 3½ per Cent. Stock, 'Caird Fund'	2,338	1	4
2,500	0	0	London and North-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	2,500	0	0
2,500	0	0	London and South-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	2,475	0	0
2,500	0	0	Canada 3½ per Cent. 1930–1950 Registered Stock, 'Caird Fund'	2,225	0	0
			Sir Frederick Bramwell's Gift:—			
78	12	7	Self-cumulating Consolidated Stock. [To be awarded in 1931 for a paper dealing with the whole question of the Prime Movers of 1931, and especially with the then relation between steam engines and internal combustion engines.]			

£21,549 18 4

JOHN PERRY, *General Treasurer.*

WITH THE BRITISH ASSOCIATION FOR THE *Cr.*

July 1, 1913, to June 30, 1914.

1913-1914. PAYMENTS.

	£	s.	d.	£	s.	d.
Rent and Office Expenses				167	0	7
Salaries, &c.				758	11	9
Printing, Binding, &c.				1,215	8	10
Expenses of Birmingham Meeting				165	11	2
Payments on account of Australian Meeting				44	4	9
Grants to Research Committees:—						
Seismological Investigations	139	0	0			
Investigation of the Upper Atmosphere	25	0	0			
International Committee on Physical and Chemical Constants	40	0	0			
Calculation of Mathematical Tables	20	0	0			
Disposal of Copies of the 'Binary Canon'	4	9	0			
Study of Hydro-aromatic Substances	15	0	0			
Dynamic Isomerism	25	0	0			
Transformation of Aromatic Nitroamines	15	0	0			
Study of Plant Enzymes	25	0	0			
Correlation of Crystalline Form with Molecular Structure	25	0	0			
Study of Solubility Phenomena	10	0	0			
List of Characteristic Fossils	5	0	0			
Geology of Ramsey Island	10	0	0			
Fauna and Flora of Trias of Western Midlands	10	0	0			
Critical Sections in Lower Palæozoic Rocks	15	0	0			
Belmullet Whaling Station	20	0	0			
Nomenclature Animalium Genera et Sub-genera	50	0	0			
Antarctic Whaling Industry	75	0	0			
Maps for School and University Use	40	0	0			
Gaseous Explosions	50	0	0			
Stress Distributions in Engineering Materials	50	0	0			
Lake Villages in the neighbourhood of Glastonbury	20	0	0			
Age of Stone Circles	20	0	0			
Artificial Islands in the Highlands of Scotland	5	0	0			
Excavations on Roman Sites in Britain	20	0	0			
Anthropometric Investigations in Cyprus	50	0	0			
Palæolithic Site in Jersey	50	0	0			
The Ductless Glands	35	0	0			
Calorimetric Observations on Man	40	0	0			
Structure and Function of the Mammalian Heart	30	0	0			
Binocular Combination of Kinematograph Pictures	0	17	0			
Structure of Fossil Plants	15	0	0			
Jurassic Flora of Yorkshire	5	0	0			
Flora of the Peat of the Kennet Valley	15	0	0			
Vegetation of Ditcham Park	14	4	3			
Physiology of Heredity	30	0	0			
Breeding Experiments with Œnotheras	19	17	4			
Mental and Physical Factors involved in Education	20	0	0			
Influence of School Books on Eyesight	2	8	9			
Character, Work, and Maintenance of Museums	10	0	0			
Corresponding Societies Committee	25	0	0			
				1,086	16	4
Grants made from 'Caird Fund'				775	0	0
Amounts paid to Grantees from Australian Government Subsidy: 1914 Meeting				14,950	0	0
Balance at Lloyds Bank, Birmingham (including accrued Interest)	1,676	12	3			
Balance at Bank of England, Western Branch: On General Account £933 1 10						
Less Overspent on 'Caird Fund' 226 6 6						
	706	15	4			
Petty Cash in hand	3	17	4			
				2,387	4	11
				£21,549	18	4

An Account of £864 6s. 6d. is outstanding due to Messrs. Spottiswoode & Co.

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balance at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees.

W. B. KEEN, *Chartered Accountant.*
December 2, 1914.

Approved—
EDWARD BRABROOK, } *Auditors.*
HERBERT McLEOD, }

GENERAL MEETINGS, 1914.

The General Meetings held in Australia will be found mentioned in the course of the Narrative on pp. 679, *seqq.* A Narrative of the Visit of Members to the Meeting of L'Association Française at Le Havre, with an account of the meetings held there, is given on p. 720.

OFFICERS OF SECTIONS AT THE AUSTRALIAN MEETING, 1914.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Prof. F. T. Trouton, F.R.S. (*in absentiâ*). *Vice-Presidents.*—Prof. E. W. Brown, F.R.S.; Prof. H. S. Carslaw, F.R.S.; Sir Oliver J. Lodge, F.R.S.; Prof. A. W. Porter, F.R.S.; Sir E. Rutherford, F.R.S. *Secretaries.*—Prof. A. S. Eddington, F.R.S. (*Recorder*); E. Gold, M.A.; Prof. S. B. McLaren, M.A.; A. O. Rankine D.Sc.; Prof. T. R. Lyle, F.R.S. (Local Sec., Melbourne); Prof. J. A. Pollock, D.Sc. (Local Sec., Sydney).

SECTION B.—CHEMISTRY.

President.—Prof. W. J. Pope, F.R.S. *Vice-Presidents.*—Prof. F. Clowes, D.Sc.; Prof. H. B. Dixon, F.R.S.; Prof. Orme Masson, F.R.S.; Prof. E. H. Rennie, D.Sc.; Prof. B. D. Steele, D.Sc. *Secretaries.*—A. Holt, D.Sc. (*Recorder*); N. V. Sidgwick, D.Sc.; D. Avery, M.Sc. (Local Sec., Melbourne); Prof. C. Fawsitt, D.Sc. (Local Sec., Sydney).

SECTION C.—GEOLOGY.

President.—Prof. Sir T. H. Holland, K.C.I.E., F.R.S. *Vice-Presidents.*—Prof. W. S. Boulton, D.Sc.; Prof. T. W. Edgeworth David, C.M.G.; H. Herman; Prof. W. J. Sollas, F.R.S.; Prof. Woolnough, D.Sc. *Secretaries.*—A. R. Dwerryhouse, D.Sc. (*Recorder*); Prof. S. H. Reynolds, M.A.; Prof. E. W. Skeats, D.Sc. (Local Sec., Melbourne); E. F. Pittman, A.R.S.M. (Local Sec., Sydney).

SECTION D.—ZOOLOGY.

President.—Prof. A. Dendy, D.Sc., F.R.S. *Vice-Presidents.*—Prof. C. B. Davenport; Prof. W. A. Haswell, F.R.S.; Prof. H. Jungersen; Dr. O. Maas; Prof. E. A. Minchin, F.R.S.; Prof. Baldwin Spencer, C.M.G., F.R.S. *Secretaries.*—Prof. H. W. Marett Tims, M.A., M.D. (*Recorder*); J. H. Ashworth, D.Sc.; R. Douglas Laurie, M.A.; T. S. Hall, D.Sc. (Local Sec., Melbourne); Prof. W. A. Haswell, D.Sc., F.R.S. (Local Sec., Sydney).

SECTION E.—GEOGRAPHY.

President.—Sir Charles P. Lucas, K.C.B., K.C.M.G. *Vice-Presidents.*—Prof. Guido Cora; Prof. T. W. Edgeworth David, C.M.G.; Capt. J. K. Davis; Prof. W. M. Davis; Sir John Forrest; Prof. A. Penck. *Secretaries.*—H. Yule Oldham, M.A. (*Recorder*); J. McFarlane, M.A.; J. A. Leach, M.Sc. (Local Sec., Melbourne); F. Poate (Local Sec., Sydney).

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Prof. E. C. K. Gonner, M.A. *Vice-Presidents.*—S. Ball; T. R. Bavin; Denison Miller; H. Y. Braddon; Harrison Moore. *Secretaries.*—Prof. A. W. Kirkaldy, M.A., M.Com. (*Recorder*); Prof. H. O. Meredith, M.A., M.Com.; G. H. Knibbs, C.M.G. (Local Sec., Melbourne); Prof. R. F. Irvine, M.A. (Local Sec., Sydney).

SECTION G.—ENGINEERING.

President.—Prof. E. G. Coker, D.Sc. *Vice-Presidents.*—W. Davidson; H. Deane, M.A.; Prof. G. Forbes, F.R.S.; Col. J. Monash; Prof. J. E. Petavel, F.R.S. *Secretaries.*—Prof. G. W. O. Howe, M.Sc. (*Recorder*); Prof. W. M. Thornton, D.Sc.; Prof. H. Payne (Local Sec., Melbourne); Prof. W. H. Warren (Local Sec., Sydney).

SECTION H.—ANTHROPOLOGY.

President.—Sir Everard im Thurn, C.B., K.C.M.G. *Vice-Presidents.*—H. Balfour, M.A.; Dr. Etheridge; Dr. A. C. Haddon, F.R.S.; Prof. F. von Luschan; Prof. Baldwin Spencer, C.M.G., F.R.S.; Prof. E. C. Stirling, F.R.S. *Secretaries.*—R. R. Marett, M.A., D.Sc. (*Recorder*); B. Malinowski, Ph.D.; Prof. R. J. A. Berry, M.D. (Local Sec., Melbourne); Prof. J. T. Wilson, M.B., F.R.S. (Local Sec., Sydney).

SECTION I.—PHYSIOLOGY.

President.—Prof. Benjamin Moore, F.R.S. *Vice-Presidents.*—Prof. W. D. Halliburton, F.R.S.; Prof. Sir E. A. Schäfer, F.R.S.; Prof. E. C. Stirling, F.R.S. *Secretaries.*—Prof. P. T. Herring, M.D. (*Recorder*); Prof. T. H. Milroy, M.D.; Prof. W. A. Osborne, D.Sc. (Local Sec., Melbourne); Prof. Sir T. P. Anderson Stuart, M.D., LL.D. (Local Sec., Sydney).

SECTION K.—BOTANY.

President.—Prof. F. O. Bower, F.R.S. *Vice-Presidents.*—J. H. Maiden, F.L.S.; Miss E. R. Saunders, F.L.S.; Prof. A. C. Seward, F.R.S. *Secretaries.*—Prof. T. Johnson, D.Sc. (*Recorder*); Miss E. N. Thomas, D.Sc.; Prof. A. J. Ewart, D.Sc. (Local Sec., Melbourne); Prof. A. Anstruther Lawson, Ph.D, D.Sc. (Local Sec., Sydney).

SECTION L.—EDUCATIONAL SCIENCE.

President.—Prof. J. Perry, F.R.S. *Vice-Presidents.*—Prof. H. E. Armstrong, F.R.S.; C. A. Buckmaster, M.A.; G. T. Moody, D.Sc. *Secretaries.*—Prof. J. A. Green, M.A. (*Recorder*); C. A. Buckmaster, M.A.; J. Smyth, M.A. (Local Sec., Melbourne); P. Board, M.A. (Local Sec., Sydney).

SECTION M.—AGRICULTURE.

President.—A. D. Hall, F.R.S. *Vice-Presidents.*—E. S. Beaven, F.C.S.; Prof. T. B. Wood, M.A. *Secretaries.*—J. Golding, F.I.C. (*Recorder*); A. Lauder, D.Sc.; Prof. T. Cherry, M.Sc. (Local Sec., Melbourne); Prof. R. D. Watt, M.A. (Local Sec., Sydney).

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES (HAVRE, 1914).

Chairman.—Sir H. G. Fordham. *Vice-Chairman.*—Sir E. Brabrook. *Secretary.*—W. Mark Webb.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[Continued on p. l.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[*Continued on p.* li.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1901, Sept. 11	Glasgow..................	Prof. A. W. Rücker, D.Sc., Sec.R.S. ...	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge..............	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15......	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25......	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield................	Rev. Prof. T. G. Bonney, F.R.S. . . .	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S..............	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S..............	376	40
1914, July-Sept....	Australia	Prof. W. Bateson, F.R.S.	172	13

¶ Including 848 Members of the South African Association.
‡‡ Grants from the Caird Fund are not included in this and subsequent sums.

ANALYSIS OF ATTENDANCES AT

[*The total attendances for the years* 1832,

Average attendance at 79 *Meetings* : 1858.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 4 Meetings beginning during *July, between* 1841 *and* 1907	1122
Average attendance at 32 Meetings beginning during *August, between* 1836 *and* 1911	1927
Average attendance at 37 Meetings beginning during *September, between* 1831 *and* 1913	1977
Attendance at 1 Meeting held in *October*, *Cambridge*, 1862 . .	1161

Meetings beginning during August.

Average attendance at—

4 Meetings beginning during the 1st week in *August* (1st– 7th) .	1905
5 ,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th) .	2130
9 ,, ,, ,, ,, 3rd ,, ,, ,, (15th–21st) .	1802
14 ,, ,, ,, ,, 4th ,, ,, ,, (22nd–31st) .	1935

at Annual Meetings of the Association—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
374	131	794	246	20	1912	£2046 0 0	£920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1‡‡	1913
139	4160‖	539‖	—	21	5044‖	4873 0 0	1086 16 4	1914

** Including 137 Members of the American Association.

‖ Special arrangements were made for Members and Associates joining locally in Australia, see p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.

THE ANNUAL MEETINGS, 1831–1913.

1835, 1843, *and* 1844 *are unknown.*]

Meetings beginning during September.

Average attendance at—

		Average Attendance
13 Meetings beginning during the 1st week in *September*	(1st– 7th).	2131
17 ,, ,, ,, ,, 2nd ,, ,, ,,	(8th–14th).	1906
5 ,, ,, ,, ,, 3rd ,, ,, ,,	(15th–21st).	2206
2 ,, ,, ,, ,, 4th ,, ,, ,,	(22nd–30th).	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1907, July 31) beginning during the 5th week in *July* (29th–31st)	1647
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

LIST OF GRANTS: AUSTRALIA, 1914.

RESEARCH COMMITTEES, ETC., APPOINTED ON BEHALF OF THE GENERAL COMMITTEE AT THE AUSTRALIAN MEETING: AUGUST, 1914.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
	SECTION A.—MATHEMATICS AND PHYSICS.	£ s. d.
Seismological Observations.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Professor J. Perry. Mr. Horace Darwin, Mr. C. Davison, Dr. R. T. Glazebrook, Mr. M. H. Gray, Professors J. W. Judd and C. G. Knott, Sir J. Larmor, Professor R. Meldola, Mr. W. E. Plummer, Dr. R. A. Sampson, Professor A. Schuster, Mr. J. J. Shaw, and Mr. G. W. Walker.	60 0 0*
Investigation of the Upper Atmosphere.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. E. Gold. Mr. C. J. P. Cave, Mr. W. H. Dines, Dr. R. T. Glazebrook, Sir J. Larmor, Professor J. E. Petavel, Professor A. Schuster, and Dr. W. Watson.	25 0 0
Annual Tables of Constants and Numerical Data, chemical, physical, and technological.	*Chairman.*—Sir W. Ramsay. *Secretary.*—Dr. W. C. McC. Lewis.	40 0 0
Calculation of Mathematical Tables.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Professor J. W. Nicholson. Mr. J. R. Airey, Mr. T. W. Chaundy, Professor Alfred Lodge, Professor L. N. G. Filon, Sir G. Greenhill, and Professors E. W. Hobson, A. E. H. Love, H. M. Macdonald, and A. G. Webster.	30 0 0

* In addition, the Council was authorised to expend a sum not exceeding £70 for the printing of circulars, &c., in connection with the Committee on Seismological Observations.

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
	SECTION B.—CHEMISTRY.	£ s. d.
The Study of Hydro-Aromatic Substances.	*Chairman.*—Professor W. H. Perkin. *Secretary.*—Professor A. W. Crossley. Dr. M. O. Forster, Dr. Le Sueur, and Dr. A. McKenzie.	15 0 0
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, and Dr. M. O. Forster.	40 0 0
The Transformation of Aromatic Nitroamines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Dr. S. Ruhemann and Dr. J. T. Hewitt.	20 0 0
The Study of Plant Enzymes, particularly with relation to Oxidation.	*Chairman.*—Mr. A. D. Hall. *Secretary.*—Dr. E. F. Armstrong. Professor H. E. Armstrong, Professor F. Keeble, and Dr. E. J. Russell.	30 0 0
Correlation of Crystalline Form with Molecular Structure.	*Chairman.*—Professor W. J. Pope. *Secretary.*—Professor H. E. Armstrong. Mr. W. Barlow and Professor W. P. Wynne.	25 0 0
Study of Solubility Phenomena.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. J. V. Eyre. Dr. E. F. Armstrong, Professor A. Findlay, Dr. T. M. Lowry, and Professor W. J. Pope.	10 0 0
Chemical Investigation of Natural Plant Products of Victoria.	*Chairman.*—Professor Orme Masson. *Secretary.*—Dr. Heber Green. Mr. J. Cronin, and Mr. P. R. H. St. John.	50 0 0
The Influence of Weather Conditions upon the Amounts of Nitrogen Acids in the Rainfall and the Atmosphere.	*Chairman.*—Professor Orme Masson. *Secretary.*—Mr. V. G. Anderson. Mr. D. Avery and Mr. H. A. Hunt.	40 0 0
Research on Non-Aromatic Diazonium Salts	*Chairman.*—Dr. F. D. Chattaway. *Secretary.*—Professor G. T. Morgan. Mr. P. G. W. Bayly and Dr. N. V. Sidgwick.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION C.—GEOLOGY.		£ s. d.
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Dr. A. R. Dwerryhouse. Dr. T. G. Bonney, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. W. Lower Carter, Professor W. J. Sollas, and Messrs. W. Hill, J. W. Stather, and J. H. Milton.	5 0 0
To consider the preparation of a List of Characteristic Fossils.	*Chairman.*—Professor P. F. Kendall. *Secretary.*—Mr. W. Lower Carter. Mr. H. A. Allen, Professor W. S. Boulton, Professor G. Cole, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, G. A. Lebour, and S. H. Reynolds, Dr. Marie C. Stopes, Mr. Cosmo Johns, Dr. J. E. Marr, Dr. A. Vaughan, Professor W. W. Watts, Mr. H. Woods, and Dr. A. Smith Woodward.	10 0 0
The Old Red Sandstone Rocks of Kiltorcan, Ireland.	*Chairman.*—Professor Grenville Cole. *Secretary.*—Professor T. Johnson. Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.	10 0 0
Fauna and Flora of the Trias of the Western Midlands.	*Chairman.*—Mr. G. Barrow. *Secretary.*—Mr. L. J. Wills. Dr. J. Humphreys, Mr. W. Campbell Smith, Mr. D. M. S. Watson, and Professor W. W. Watts.	10 0 0
To excavate Critical Sections in the Lower Palæozoic Rocks of England and Wales.	*Chairman.* — Professor W. W. Watts. *Secretary.* — Professor W. G. Fearnsides. Professor W. S. Boulton, Mr. E. S. Cobbold, Mr. V. C. Illing, Dr. Lapworth, and Dr. J. E. Marr.	15 0 0
SECTION D.—ZOOLOGY.		
To investigate the Biological Problems incidental to the Belmullet Whaling Station.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Professor J. Stanley Gardiner. Professor W. A. Herdman, Rev. W. Spotswood Green, Mr. E. S. Goodrich, Professor H. W. Marett Tims, and Mr. R. M. Barrington.	45 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
Nomenclator Animalium Genera et Sub-genera.	*Chairman.*—Dr. Chalmers Mitchell. *Secretary.*—Rev. T. R. R. Stebbing. Dr. M. Laurie, Prof. Marett Tims, and Dr. A. Smith Woodward.	25 0 0
An investigation of the Biology of the Abrolhos Islands and the North-west Coast of Australia (north of Shark's Bay to Broome), with particular reference to the Marine Fauna.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor W. J. Dakin. Dr. J. H. Ashworth and Professor F. O. Bower.	40 0 0
To obtain, as nearly as possible, a representative Collection of Marsupials for work upon (*a*) the Reproductive Apparatus and Development, (*b*) the Brain.	*Chairman.*—Professor A. Dendy. *Secretaries.*—Professors T. Flynn and G. E. Nicholls. Professor E B. Poulton and Professor H. W. Marett Tims.	100 0 0

Section E.—GEOGRAPHY.

Subject for Investigation, or Purpose	Members of Committee	Grants
To investigate the Conditions determining the Selection of Sites and Names for Towns, with special reference to Australia.	*Chairman.*—Sir C. P. Lucas. *Secretary.*—Mr. H. Yule Oldham. Mr. G. G. Chisholm, Professor A. J. Herbertson, and Professor J. L. Myres.	20 0 0
The Hydrographical Survey of Stor Fjord, Spitsbergen, by Dr. W. S. Bruce.	*Chairman.*—Mr. G. G. Chisholm. *Secretary.*—Mr. J. McFarlane. Dr. R. N. Rudmose Brown, Capt. J. K. Davis, and Mr. H. Yule Oldham.	50 0 0
To aid in the preparation of a Bathymetrical Chart of the Southern Ocean between Australia and Antarctica.	*Chairman.*—Professor T.W. Edgeworth David. *Secretary.*—Capt. J. K. Davis. Professor J. W. Gregory, Sir C. P. Lucas, and Professor Orme Masson.	100 0 0

Section F.—ECONOMIC SCIENCE AND STATISTICS.

Subject for Investigation, or Purpose	Members of Committee	Grants
The question of Fatigue from the Economic Standpoint, if possible in co-operation with Section I, Sub-section of Psychology.	*Chairman.*—Professor Muirhead. *Secretary.*—Miss B. L. Hutchins. Miss A. M. Anderson, Professor F. A. Bainbridge, Mr. E. Cadbury, Professor S. J. Chapman, Mr. P. Sargant Florence, Professor Stanley Kent, Miss M. C. Matheson, Mrs. Meredith, Dr. C. S. Myers, Mr. J. W. Ramsbottom and Dr. Jenkins Robb.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
Section G.—ENGINEERING.		£ s. d.
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Dr. Dugald Clerk. *Secretary.*—Professor W. E. Dalby. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, E. G. Coker, and H. B. Dixon, Drs. R. T. Glazebrook and J. A. Harker, Colonel H. C. L. Holden, Professors B. Hopkinson and J. E. Petavel, Captain H. Riall Sankey, Professor A. Smithells, Professor W. Watson, Mr. D. L. Chapman, and Mr. H. E. Wimperis.	50 0 0
To report on certain of the more complex Stress Distributions in Engineering Materials.	*Chairman.*—Professor J. Perry. *Secretaries.* — Professors E. G. Coker and J. E. Petavel. Professor A. Barr, Dr. Chas. Chree, Mr. Gilbert Cook, Professor W. E. Dalby, Sir J. A. Ewing, Professor L. N. G. Filon, Messrs. A. R. Fulton and J. J. Guest, Professors J. B. Henderson and A. E. H. Love, Mr. W. Mason, Sir Andrew Noble, Messrs. F. Rogers and W. A. Scoble, Dr. T. E. Stanton, and Mr. J. S. Wilson.	50 0 0
Section H.—ANTHROPOLOGY.		
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Mr. Willoughby Gardner. Professor W. Ridgeway, Sir Arthur J. Evans, Sir C. H. Read, Mr. H. Balfour, and Dr. A. Bulleid.	20 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Sir C. H. Read. *Secretary.*—Mr. H. Balfour. Dr. G. A. Auden, Professor W. Ridgeway, Dr. J. G. Garson, Sir A. J. Evans, Dr. R. Munro, Professors Boyd Dawkins and J. L. Myres, Mr. A. L. Lewis, and Mr. H. Peake.	20 0 0
To investigate the Physical Characters of the Ancient Egyptians.	*Chairman.*—Professor G. Elliot Smith. *Secretary.*—Dr. F. C. Shrubsall. Dr. F. Wood-Jones, Dr. A. Keith, and Dr. C. G. Seligman.	34 16 6

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To conduct Anthropometric Investigations in the Island of Cyprus.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. F. C. Shrubsall. Dr. A. C. Haddon.	50 0 0
To excavate a Palæolithic Site in Jersey.	*Chairman.*—Dr. R. R. Marett. *Secretary.*—Colonel Warton. Dr. C. W. Andrews, Mr. H. Balfour, Dr. Dunlop, Mr. G. de Gruchy, and Professor A. Keith.	50 0 0
To conduct Archæological Investigations in Malta.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. T. Ashby. Mr. H. Balfour, Dr. A. C. Haddon, and Dr. R. R. Marett.	10 0 0
To prepare and publish Miss Byrne's Gazetteer and Map of the Native Tribes of Australia.	*Chairman.*—Professor Baldwin Spencer. *Secretary.*—Dr. R. R. Marett. Mr. H. Balfour.	20 0 0

SECTION I.—PHYSIOLOGY.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Ductless Glands.	*Chairman.*—Sir E. A. Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, and Mrs. W. H. Thompson.	35 0 0
To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—general and local—with special reference to Deaths by or during Anæsthesia, and their possible diminution.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Sir F. W. Hewitt. Dr. Blumfeld, Mr. J. A. Gardner, and Dr. G. A. Buckmaster.	20 0 0
Electromotive Phenomena in Plants.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Mrs. Waller. Professors J. B. Farmer, T. Johnson, and Veley, and Dr. F. O'B. Ellison.	20 0 0
To investigate the Physiological and Psychological Factors in the production of Miners' Nystagmus.	*Chairman.*—Professor J. H. Muirhead. *Secretary.*—Dr. T. G. Maitland. Dr. J. Jameson Evans and Dr. C. S. Myers.	20 0 0
The Significance of the Electromotive Phenomena of the Heart.	*Chairman.*—Professor W. D. Halliburton. *Secretary.*—Dr. Florence Buchanan. Professor A. D. Waller.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
Metabolism of Phosphates.	*Chairman.*—Professor W. A. Osborne. *Secretary.*—Miss Kincaid. Dr. Rothera.	20 0 0
Section K.—BOTANY.		
The Structure of Fossil Plants.	*Chairman.*—Professor F. W. Oliver. *Secretary.*—Professor F. E. Weiss. Mr. E. Newell Arber, Professor A. C. Seward, and Dr. D. H. Scott.	15 0 0
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Professor F. F. Blackman. *Secretary.*—Mr. R. P. Gregory. Professors Bateson and Keeble and Miss E. R. Saunders.	45 0 0
The Renting of Cinchona Botanic Station in Jamaica.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor R. H. Yapp. Professors R. Buller, F. W. Oliver, and F. E. Weiss.	25 0 0
To carry out a Research on the Influence of varying percentages of Oxygen and of various Atmospheric Pressures upon Geotropic and Heliotropic Irritability and Curvature.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor A. J. Ewart. Professor F. F. Blackman.	50 0 0
The Collection and Investigation of Material of Australian Cycadaceæ, especially Bowenia from Queensland and Macrozaunia from West Australia.	*Chairman.*—Professor A. A. Lawson. *Secretary.*—Professor T. G. B. Osborn. Professor A. C. Seward.	25 0 0
To cut Sections of Australian Fossil Plants, with especial reference to a specimen of Zygopteris from Simpson's Station, Barraba, N.S.W.	*Chairman.*—Professor Lang. *Secretary.*—Professor T. G. B. Osborn. Professor T. W. E. David and Professor A. C. Seward.	25 0 0
Section L.—EDUCATIONAL SCIENCE.		
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—Professor J. A. Green. Professor J. Adams, Dr. G. A. Auden, Sir E. Brabrook, Dr. W. Brown, Mr. C. Burt, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor W. McDougall, Dr. T. P. Nunn, Dr. W. H. R. Rivers, Dr. F. C. Shrubsall, Mr. H. Bompas Smith, Dr. C. Spearman, and Mr. A. E. Twentyman.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Influence of School Books upon Eyesight.	*Chairman.*—Dr. G. A. Auden. *Secretary.*—Mr. G. F. Daniell. Mr. C. H. Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Mr. J. L. Holland, Dr. W. E. Sumpner, and Mr. Trevor Walsh.	5 0 0
To inquire into and report on the number, distribution and respective values of Scholarships, Exhibitions, and Bursaries held by University Students during their undergraduate course, and on funds private and open available for their augmentation.	*Chairman.*—Sir Henry Miers. *Secretary.*—Professor Marcus Hartog. Miss Lilian J. Clarke, Miss B. Foxley, Professor H. Bompas Smith, and Principal Griffiths.	5 0 0
To examine, inquire into, and report on the Character, Work, and Maintenance of Museums, with a view to their Organisation and Development as Institutions for Education and Research; and especially to inquire into the Requirements of Schools.	*Chairman.*—Professor J. A. Green. *Secretaries.*—Mr. H. Bolton and Dr. J. A. Clubb. Dr. F. A. Bather, Mr. C. A. Buckmaster, Mr. Ernest Gray, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood and P. Newberry, Sir Richard Temple, Mr. H. Hamshaw Thomas, Professor F. E. Weiss, Mrs. J. White, Rev. H. Browne, Drs. A. C. Haddon and H. S. Harrison, Mr. Herbert R. Rathbone, and Dr. W. M. Tattersall.	20 0 0

CORRESPONDING SOCIETIES.

Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. Mark Webb. Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.	25 0 0

2. *Not receiving Grants of Money.**

Subject for Investigation, or Purpose	Members of Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
Radiotelegraphic Investigations.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr. S. G. Brown, Dr. C. Chree, Professor A. S. Eddington, Dr. Erskine-Murray, Professors J. A. Fleming, G. W. O. Howe, H. M. Macdonald, and J. W. Nicholson, Sir H. Norman, Captain H. R. Sankey, Dr. A. Schuster, Dr. W. N. Shaw, Professor S. P. Thompson, and Professor H. H. Turner.
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*— *Secretary.*—Dr. W. G. Duffield. Rev. A. L. Cortie, Dr. W. J. S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H. Turner.
*Determination of Gravity at Sea.	*Chairman.*—Professor A. E. Love. *Secretary.*—Professor W. G. Duffield. Mr. T. W. Chaundy and Professors A. S. Eddington and H. H. Turner.
SECTION B.—CHEMISTRY.	
Research on the Utilization of Brown Coal Bye-Products.	*Chairman.*—Professor Orme Masson. *Secretary.*—Mr. P. G. W. Bayly. Mr. D. Avery.
To report on the Botanical and Chemical Characters of the Eucalypts and their Correlation.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. H. G. Smith. Dr. Andrews, Mr. R. T. Baker, Professor F. O. Bower, Mr. R. H. Cambage, Professor A. J. Ewart, Professor C. B. Fawsitt, Dr. Heber Green, Dr. Cuthbert Hall, Professors Orme Masson, Rennie, and Robinson, and Mr. St. John.
SECTION C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretaries.*—Professors W. W. Watts and S. H. Reynolds. Mr. G. Bingley, Dr. T. G. Bonney, Mr. C. V. Crook, Professor E. J. Garwood, and Messrs. R. Kidston, A. S. Reid, J. J. H. Teall, R. Welch, and W. Whitaker.
To consider the Preparation of a List of Stratigraphical Names, used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.	*Chairman.*—Dr. J. E. Marr. *Secretary.*—Dr. F. A. Bather. Professor Grenville Cole, Mr. Bernard Hobson, Professor Lebour, Dr. J. Horne, Dr. A. Strahan, and Professor W. W. Watts.

* Excepting the case of Committees receiving grants from the Caird Fund (p. lxviii).

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
To consider the Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Professor E. W. Skeats. Mr. W. S. Dun, Sir T. H. Holland, Professor Howchin, Mr. G. W. Lamplugh, and Professor W. G. Woolnough.

SECTION D.—ZOOLOGY.

*To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Mr. E. S. Goodrich. *Secretary.*—Dr. J. H. Ashworth. Mr. G. P. Bidder, Professor F. O. Bower, Drs. W. B. Hardy and S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, and Dr. A. D. Waller.
To investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge as to the economic status of many of our commoner birds affecting rural science.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Mr. H. S. Leigh. Mr. J. N. Halbert, Professor Robert Newstead, Messrs. Clement Reid, A. G. L. Rogers, and F. V. Theobald, Professor F. E. Weiss, Dr. C. Gordon Hewitt, and Professors S. J. Hickson, F. W. Gamble, G. H. Carpenter, and J. Arthur Thomson.
To defray expenses connected with work on the Inheritance and Development of Secondary Sexual Characters in Birds.	*Chairman.*—Professor G. C. Bourne. *Secretary.*—Mr. Geoffrey Smith. Mr. E. S. Goodrich, Dr. W. T. Calman, and Dr. Marett Tims.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Sir E. Ray Lankester. *Secretary.*—Professor S. J. Hickson. Professors G. C. Bourne, J. Cossar Ewart, M. Hartog, and W. A. Herdman, Mr. M. D. Hill, Professors J. Graham Kerr and Minchin, Dr. P. Chalmers Mitchell, Professors E. B. Poulton and Stanley Gardiner, and Dr. A. E. Shipley.
To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor J. P. Hill, and Mr. E. S. Goodrich.
To formulate a Definite System on which Collectors should record their captures.	*Chairman.*—Professor J. W. H. Trail. *Secretary.*—Mr. F. Balfour Browne. Drs. Scharff and E. J. Bles, Professors G. H. Carpenter and E. B. Poulton, and Messrs. A. G. Tansley and R. Lloyd Praeger.

* See note on preceding page.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
A Natural History Survey of the Isle of Man.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. P. M. C. Kermode. Dr. W. T. Calman, Rev. J. Davidson, Mr. G. W. Lamplugh, Professor E. W. MacBride, and Lord Raglan.

Section E.—GEOGRAPHY.

To inquire into the choice and style of Atlas, Textual, and Wall Maps for School and University Use.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Rev. W. J. Barton. Professors R. L. Archer and R. N. R. Brown, Mr. G. G. Chisholm, Professor H. N. Dickson, Mr. A. R. Hinks, Mr. O. J. R. Howarth, Sir Duncan Johnston, and Mr. E. A. Reeves.

Section G.—ENGINEERING.

To consider and report on the Standardization of Impact Tests.	*Chairman.*—Professor W. H. Warren. *Secretary.*—Mr. J. Vicars. Mr. Julius, Professor Gibson, Mr. Houghton, and Professor Payne.

Section H.—ANTHROPOLOGY.

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Sir C. H. Read. *Secretary.*— Dr. G. A. Auden, Mr. E. Heawood, and Professor J. L. Myres.
To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. W. L. H. Duckworth, Sir A. J. Evans, Professor W. Ridgeway, and Dr. F. C. Shrubsall.
To report on the present state of knowledge of the Prehistoric Civilisation of the Western Mediterranean with a view to future research.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Dr. T. Ashby. Dr. W. L. H. Duckworth, Mr. D. G. Hogarth, Sir A. J. Evans, Professor J. L. Myres, and Mr. A. J. B. Wace.
To conduct Excavations in Easter Island.	*Chairman.*—Dr. A. C. Haddon. *Secretary.*—Dr. W. H. R. Rivers. Mr. R. R. Marett and Dr. C. G. Seligman.
To report on Palæolithic Sites in the West of England.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Dr. W. L. H. Duckworth. Professor A. Keith.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
The Teaching of Anthropology.	*Chairman.*—Sir Richard Temple. *Secretary.*—Dr. A. C. Haddon. Sir E. F. im Thurn, Mr. W. Crooke, Dr. C. G. Seligman, Professor G. Elliot Smith, Dr. R. R. Marett, Professor P. E. Newberry, Dr. G. A. Auden, Professors T. H. Bryce, P. Thompson, R. W. Reid, H. J. Fleure, and J. L. Myres, Sir B. C. A. Windle, and Professors R. J. A. Berry, Baldwin Spencer, Sir T. Anderson Stuart, and E. C. Stirling.
To excavate Early Sites in Macedonia.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Mr. A. J. B. Wace. Professors R. C. Bosanquet and J. L. Myres.
To report on the Distribution of Bronze Age Implements.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Mr. H. Peake. Professor W. Ridgeway, Mr. H. Balfour, Sir C. H. Read, Professor W. Boyd Dawkins, and Dr. R. R. Marett.
To investigate and ascertain the Distribution of Artificial Islands in the lochs of the Highlands of Scotland.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Prof. J. L. Myres. Professors T. H. Bryce and W. Ridgeway, Dr. A. Low, and Mr. A. J. B. Wace.
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Mr. Willoughby Gardner, and Professor J. L. Myres.

SECTION I.—PHYSIOLOGY.

Subject for Investigation, or Purpose	Members of Committee
The Dissociation of Oxy-Hæmoglobin at High Altitudes.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. J. Barcroft. Dr. W. B. Hardy.
Colour Vision and Colour Blindness.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. Edridge-Green. Professor Leonard Hill, Professor A. W. Porter, Dr. A. D. Waller, Professor C. S. Sherrington, and Dr. F. W. Mott.
Calorimetric Observations on Man in Health and in Febrile Conditions.	*Chairman.*—Professor J. S. Macdonald. *Secretary.*—Dr. Francis A. Duffield. Dr. Keith Lucas.
Further Researches on the Structure and Function of the Mammalian Heart.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Professor Stanley Kent. Dr. Florence Buchanan.
The Binocular Combination of Kinematograph Pictures of different Meaning, and its relation to the Binocular Combination of simpler Perceptions.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—T. H. Pear.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section K.—BOTANY.	
To consider and report on the advisability and the best means of securing definite Areas for the Preservation of Types of British Vegetation.	*Chairman.*—Professor F. E. Weiss. *Secretary.*—Mr. A. G. Tansley. Professor J. W. H. Trail, Mr. R. Lloyd Praeger, Professor F. W. Oliver, Professor R. W. Phillips, Dr. C. E. Moss, and Messrs. G. C. Druce and H. W. T. Wager.
The Investigation of the Vegetation of Ditcham Park, Hampshire.	*Chairman.*—Mr. A. G. Tansley. *Secretary.*—Mr. R. S. Adamson. Dr. C. E. Moss and Professor R. H. Yapp.
Section L.—EDUCATIONAL SCIENCE.	
To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary and Higher Education.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Major E. Gray. Miss Coignan, Principal Griffiths, Dr. C. W. Kimmins, Sir Horace Plunkett, Mr. H. Ramage, Professor M. E. Sadler, and Rt. Rev. J. E. C. Welldon.
The Aims and Limits of Examinations.	*Chairman.*—Professor M. E. Sadler. *Secretary.*—Mr. P. J. Hartog. Mr. D. P. Berridge, Professor G. H. Bryan, Mr. W. D. Eggar, Professor R. A. Gregory, Principal E. H. Griffiths, Miss C. L. Laurie, Dr. W. McDougall, Mr. David Mair, Dr. T. P. Nunn, Sir W. Ramsay, Rt. Rev. J. E. C. Welldon, Dr. Jessie White, and Mr. G. U. Yule.

Communications ordered to be printed in extenso.

Section A.—Joint Discussion with Section B on the Structure of Atoms and Molecules.

Section A.—Dr. E. Goldstein: Salts coloured by Cathode Rays.

Section C.—Discussion on Physiography of Arid Lands.

Section D.—Discussion on Antarctica.

Section I.—Dr. J. W. Barrett: The Problem of the Visual Requirements of the Sailor and the Railway Employee.

Section M.—Dr. Lyman J. Briggs: Dry-farming Investigations in the United States.

Resolutions referred to the Council for consideration, and, if desirable, for action.

(a) *From Sections A and C.*

'That in view of the fact that meteorites, which convey information of world-wide importance, are sometimes disposed of privately, in such a way as to deprive the public of this information, the Council be requested to take such steps as may initiate international legislation on the matter.'

(b) *From Section A.*

'That the British Association respectfully urge the need for the establishment in Australia of a Bureau of Weights and Measures, with the view of legalising the

metric system as an alternative standard (as in Great Britain). They would also cordially welcome the inclusion of Australia as a member of the International Convention.'

(c) *From Section A.*

'That the British Association learns with great satisfaction that the State Government of Victoria has put a definite annual grant at the disposal of the Director of the Melbourne Observatory for printing the work already done at the Observatory. It is very desirable that every effort should be made to publish as soon as possible the arrears accumulated during the past thirty years.'

(d) *From Sections C and E.*

'The Committees of the Geographical and Geological Sections of the British Association wish to draw attention to the high scientific value and practical importance of systematic glacial observation in New Zealand, and venture to urge upon the favourable consideration of the Government of the Dominion the great importance of continuing and extending the work which is now being done in this direction by officers of the Government, as far as possible in conformity with the methods adopted by the Commission Internationale des Glaciers.'

(e) *From Sections C and E.*

'The Geographical and Geological Sections of the British Association respectfully request the Secretary of State for the Colonies to establish on certain islands in the Coral Seas—in extension of a plan that has lately been presented to His Excellency the Governor of Fiji, and by him submitted for the favourable consideration of the Legislative Council of that Colony—a number of bench-marks, with respect to which the mean level of the sea surface shall be accurately determined once every ten years, in order to discover, after a century or longer, whether any change takes place in the altitude of land with respect to the sea.

'It is suggested that a uniform plan for this work be prepared by the appropriate Government department, and that an abstract of the results obtained for each decade be forwarded to the British Association for publication.'

(f) *From Section C.*

'That the Committee of Section C submits for favourable consideration to the committee of Recommendations of the British Association the question of urging the Federal and State Governments in Australia to co-operate in undertaking, as soon as possible, a gravity survey of the Earth's crust within the area of the Commonwealth. The Committee suggests that the work be commenced in the region of the Great Rift Valley of Australia, extending from near Adelaide northwards to Lake Eyre.'

(g) *From Section E.*

'The Committee of Section E most warmly favours the project of a uniform Map of the World on a scale of 1 : 1,000,000, and expresses the hope that the sheets of Australia may be undertaken as soon as possible, on the same plan as has lately been adopted by the War Office in London for a map of Africa, and by the Geological Survey in Washington for the U.S.A. To this end they regard it as desirable that in the extensive surveys which the several States of the Commonwealth are carrying on, as much stress should be laid upon the geographical features of the land, the watercourses and the mountains, as upon property boundaries, and that in particular the determination of altitudes should be carried on, in order eventually to provide the basis for contoured maps.'

(h) *From Sections D and K.*

'It is with much pleasure that we ascertain that a Bill has been prepared by the present Government of South Australia for the establishment of a reserve of 300 square miles situated on the western end of Kangaroo Island for the preservation of the fauna and flora, which are fast being exterminated on the mainland, and that this reserve will be placed under the control of a Board nominated by the University of Adelaide and the Government. We trust that this Bill will become law at an early date.'

(i) *From the Committee of Recommendations.*

'That in view of the successful issue of the Australian Meeting of the Association, the Council be asked to consider the best means of bringing into closer relationship the British Association and scientific representatives from the Dominions overseas.'

Synopsis of Grants of Money (exclusive of Grants from the Caird Fund) appropriated for Scientific Purposes on behalf of the General Committee at the Australian Meeting, September 1914. The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	†60	0	0
*Shaw, Dr. W. N.—Upper Atmosphere	25	0	0
*Ramsay, Sir W.—Annual Table of Constants and Numerical Data	40	0	0
*Hill, Professor M. J. M.—Calculation of Mathematical Tables	30	0	0

Section B.—Chemistry.

	£	s.	d.
*Perkin, Dr. W. H.—Study of Hydro-aromatic Substances	15	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	40	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitro-amines	20	0	0
*Hall, A. D.—Study of Plant Enzymes	30	0	0
*Pope, Professor W. J.—Correlation of Crystalline Form with Molecular Structure	25	0	0
*Armstrong, Professor H. E.—Solubility Phenomena	10	0	0
Masson, Professor Orme.—Chemical Investigation of Natural Plant Products	50	0	0
Masson, Professor Orme.—Influence of Weather Conditions on Nitrogen Acids in Rainfall	40	0	0
Chattaway, Dr. F. D.—Non-aromatic Diazonium Salts	10	0	0

Section C.—Geology.

	£	s.	d.
*Tiddeman, R. H.—Erratic Blocks	5	0	0
*Kendall, Professor P. F.—List of Characteristic Fossils	10	0	0
*Cole, Professor Grenville.—Old Red Sandstone Rocks of Kiltorcan	10	0	0
*Barrow, G.—Trias of Western Midlands	10	0	0
*Watts, Professor W. W.—Sections in Lower Palæozoic Rocks	15	0	0
Carried forward	£445	0	0

* Reappointed.

† In addition, the Council are authorised to expend a sum not exceeding £70 on the printing of circulars, &c., in connection with the Committee on Seismological Observations.

	£	s.	d.
Brought forward	445	0	0
Section D.—Zoology.			
*Shipley, Dr. A. E.—Belmullet Whaling Station	45	0	0
*Mitchell, Dr. Chalmers.—Nomenclator Animalium	25	0	0
Herdman, Professor W. A.—Biology of Abrolhos Islands	40	0	0
Dendy, Professor A.—Collection of Marsupials	100	0	0
Section E.—Geography.			
Lucas, Sir C. P.—Conditions determining Selection of Sites and Names for Towns	20	0	0
Chisholm, G. G.—Survey of Stor Fjord, Spitsbergen	50	0	0
David, Professor T. W. E.—Antarctic Bathymetrical Chart	100	0	0
Section F.—Economic Science and Statistics.			
*Muirhead, Professor J. F.—Fatigue from Economic Standpoint	30	0	0
Section G.—Engineering.			
*Clerk, Dr. Dugald.—Gaseous Explosions	50	0	0
*Perry, Professor J.—Stress Distributions	50	0	0
Section H.—Anthropology.			
*Dawkins, Professor Boyd.—Lake Villages in the neighbourhood of Glastonbury	20	0	0
*Read, Sir C. H.—Age of Stone Circles	20	0	0
*Smith, Professor G. Elliot.—Physical Characters of the Ancient Egyptians	34	16	6
*Myres, Professor J. L.—Anthropometric Investigations in Cyprus	50	0	0
*Marett, Dr. R. R.—Palæolithic Site in Jersey	50	0	0
Myres, Professor J. L.—Excavations in Malta	10	0	0
Spencer, Professor Baldwin.—Gazetteer and Map of Native Tribes of Australia	20	0	0
Section I.—Physiology			
*Schäfer, Sir E. A.—The Ductless Glands	35	0	0
*Waller, Dr. A. D.—Anæsthetics	20	0	0
*Waller, Dr. A. D.—Electromotive Phenomena in Plants	20	0	0
*Muirhead, Professor J. F.—Miners' Nystagmus	20	0	0
Osborne, Professor W. A.—Metabolism of Phosphates	20	0	0
Halliburton, Professor W. D.—Electromotive Phenomena of the Heart	20	0	0
Section K.—Botany.			
*Oliver, Professor F. W.—Structure of Fossil Plants	15	0	0
*Blackman, Professor F. F.—Physiology of Heredity	45	0	0
*Bower, Professor F. O.—Renting of Cinchona Botanic Station, Jamaica	25	0	0
Carried forward	£1,379	16	6

* Reappointed.

	£	s.	d.
Brought forward	1,379	16	6
Bower, Professor F. O.—Influence of Percentages of Oxygen, &c., on Geotropic and Heliotropic Irritation and Curvature	50	0	0
Lawson, Professor A. A.—Australian Cycadaceæ	25	0	0
Lang, Professor W. H.—Sections of Australian Fossil Plants	25	0	0
Section L.—Education.			
*Myers, Dr. C. S.—Mental and Physical Factors involved in Education	30	0	0
*Auden, Dr. G. A.—Influence of School Books on Eyesight...	5	0	0
*Miers, Sir H.—Scholarships, &c., held by University Students	5	0	0
*Green, Professor J. A.—Character, Work, and Maintenance of Museums	20	0	0
Corresponding Societies Committee.			
*Whitaker, W.—For Preparation of Report	25	0	0
Total†	£1,634	16	6

* Reappointed.

† Including £70 as specified in footnote on p. lxvi.

Caird Fund.

An unconditional gift of 10,000*l.* was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council in its Report to the General Committee at the Birmingham Meeting made certain recommendations as to the administration of this Fund. These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

The following allocations have been made from the Fund by the Council to December 1914 :—

Naples Zoological Station Committee (p. lxi).—50*l.* (1912–13) ; 100*l.* (1913–14) ; 100*l.* annually in future, subject to the adoption of the Committee's report.

Seismology Committee (p. lii).—100*l.* (1913–14) ; 100*l.* annually in future, subject to the adoption of the Committee's report.

Radiotelegraphic Committee (p. lx). 500*l.* (1913–14).

Magnetic Re-survey of the British Isles (in collaboration with the Royal Society).—250*l.*

Committee on Determination of Gravity at Sea (p. lx).—100*l.* (1914–15).

Mr. F. Sargent, Bristol University, in connection with his Astronomical Work.—10*l.* (1914).

Sir J. K. Caird, on September 10, 1913, made a further gift of 1,000*l.* to the Association, to be devoted to the study of Radio-activity.

PRESIDENT'S ADDRESS.

ADDRESS

BY

Professor WILLIAM BATESON, M.A., F.R.S., PRESIDENT.

Part I.—MELBOURNE.[1]

The outstanding feature of this Meeting must be the fact that we are here—in Australia. It is the function of a President to tell the Association of advances in science, to speak of the universal rather than of the particular or the temporary. There will be other opportunities of expressing the thoughts which this event must excite in the dullest heart, but it is right that my first words should take account of those achievements of organisation and those acts of national generosity by which it has come to pass that we are assembled in this country. Let us, too, on this occasion, remember that all the effort, and all the goodwill, that binds Australia to Britain would have been powerless to bring about such a result had it not been for those advances in science which have given man a control of the forces of Nature. For we are here by virtue of the feats of genius of individual men of science, giant-variations from the common level of our species; and since I am going soon to speak of the significance of individual variation, I cannot introduce that subject better than by calling to remembrance the line of pioneers in chemistry, in physics, and in engineering, by the working of whose rare—or, if you will, abnormal—intellects a meeting of the British Association on this side of the globe has been made physically possible.

I have next to refer to the loss within the year of Sir David Gill, a former President of this Association, himself one of the outstanding great. His greatness lay in the power of making big foundations. He built up the Cape Observatory; he organised international geodesy; he conceived and carried through the plans for the photography of the whole sky, a work in which Australia is bearing a conspicuous part.

[1] Delivered in Melbourne on Friday, August 14, 1914.

Astronomical observation is now organised on an international scale, and of this great scheme Gill was the heart and soul. His labours have ensured a base from which others will proceed to discovery otherwise impossible. His name will be long remembered with veneration and gratitude.

As the subject of the Addresses which I am to deliver here and in Sydney I take *Heredity*. I shall attempt to give the essence of the discoveries made by Mendelian or analytical methods of study, and I shall ask you to contemplate the deductions which these physiological facts suggest in application both to evolutionary theory at large and to the special case of the natural history of human society.

Recognition of the significance of heredity is modern. The term itself in its scientific sense is no older than Herbert Spencer. Animals and plants are formed as pieces of living material split from the body of the parent organisms. Their powers and faculties are fixed in their physiological origin. They are the consequence of a genetic process, and yet it is only lately that this genetic process has become the subject of systematic research and experiment. The curiosity of naturalists has of course always been attracted to such problems; but that accurate knowledge of genetics is of paramount importance in any attempt to understand the nature of living things has only been realised quite lately even by naturalists, and with casual exceptions the laity still know nothing of the matter. Historians debate the past of the human species, and statesmen order its present or profess to guide its future as if the animal Man, the unit of their calculations, with his vast diversity of powers, were a homogeneous material, which can be multiplied like shot.

The reason for this neglect lies in ignorance and misunderstanding of the nature of Variation; for not until the fact of congenital diversity is grasped, with all that it imports, does knowledge of the system of hereditary transmission stand out as a primary necessity in the construction of any theory of Evolution, or any scheme of human polity.

The first full perception of the significance of variation we owe to Darwin. The present generation of evolutionists realises perhaps more fully than did the scientific world in the last century that the theory of Evolution had occupied the thoughts of many and found acceptance with not a few before ever the 'Origin' appeared. We have come also to the conviction that the principle of Natural Selection cannot have been the chief factor in delimiting the species of animals and plants, such as we now with fuller knowledge see them actually to be. We are even more sceptical as to the validity of that appeal to changes in the conditions of life as direct causes of modification, upon which latterly at all events Darwin laid much emphasis. But that he was the

first to provide a body of fact demonstrating the variability of living things, whatever be its causation, can never be questioned.

There are some older collections of evidence, chiefly the work of the French school, especially of Godron[2]—and I would mention also the almost forgotten essay of Wollaston[3]—these however are only fragments in comparison. Darwin regarded variability as a property inherent in living things, and eventually we must consider whether this conception is well founded; but postponing that inquiry for the present, we may declare that with him began a general recognition of variation as a phenomenon widely occurring in Nature.

If a population consists of members which are not alike but differentiated, how will their characteristics be distributed among their offspring? This is the problem which the modern student of heredity sets out to investigate. Formerly it was hoped that by the simple inspection of embryological processes the modes of heredity might be ascertained, the actual mechanism by which the offspring is formed from the body of the parent. In that endeavour a noble pile of evidence has been accumulated. All that can be made visible by existing methods has been seen, but we come little if at all nearer to the central mystery. We see nothing that we can analyse further—nothing that can be translated into terms less inscrutable than the physiological events themselves. Not only does embryology give no direct aid, but the failure of cytology is, so far as I can judge, equally complete. The chromosomes of nearly related creatures may be utterly different both in number, size, and form. Only one piece of evidence encourages the old hope that a connection might be traceable between the visible characteristics of the body and those of the chromosomes. I refer of course to the accessory chromosome, which in many animals distinguishes the spermatozoon about to form a female in fertilisation. Even it however cannot be claimed as the cause of sexual differentiation, for it may be paired in forms closely allied to those in which it is unpaired or accessory. The distinction may be present or wanting, like any other secondary sexual character. Indeed, so long as no one can show consistent distinctions between the cytological characters of somatic tissues in the same individual we can scarcely expect to perceive such distinctions between the chromosomes of the various types.

For these methods of attack we now substitute another, less ambitious, perhaps, because less comprehensive, but not less direct. If we cannot see how a fowl by its egg and its sperm gives rise to

[2] *De l'Espèce et des Races dans les Êtres Organisés*, 1859.

[3] *On the Variation of Species*, 1856.

a chicken or how a Sweet Pea from its ovule and its pollen grain produces another Sweet Pea, we at least can watch the system by which the differences between the various kinds of fowls or between the various kinds of Sweet Peas are distributed among the offspring. By thus breaking the main problem up into its parts we give ourselves fresh chances. This analytical study we call Mendelian because Mendel was the first to apply it. To be sure, he did not approach the problem by any such line of reasoning as I have sketched. His object was to determine the genetic definiteness of species; but though in his writings he makes no mention of inheritance it is clear that he had the extension in view. By cross-breeding he combined the characters of varieties in mongrel individuals and set himself to see how these characters would be distributed among the individuals of subsequent generations. Until he began this analysis nothing but the vaguest answers to such a question had been attempted. The existence of any orderly system of descent was never even suspected. In their manifold complexity human characteristics seemed to follow no obvious system, and the fact was taken as a fair sample of the working of heredity.

Misconception was especially brought in by describing descent in terms of 'blood.' The common speech uses expressions such as consanguinity, pure-blooded, half-blood, and the like, which call up a misleading picture to the mind. Blood is in some respects a fluid, and thus it is supposed that this fluid can be both quantitatively and qualitatively diluted with other bloods, just as treacle can be diluted with water. Blood in primitive physiology being the peculiar vehicle of life, at once its essence and its corporeal abode, these ideas of dilution and compounding of characters in the commingling of bloods inevitably suggest that the ingredients of the mixture once combined are inseparable, that they can be brought together in any relative amounts, and in short that in heredity we are concerned mainly with a quantitative problem. Truer notions of genetic physiology are given by the Hebrew expression 'seed.' If we speak of a man as 'of the blood-royal' we think at once of plebeian dilution, and we wonder how much of the royal fluid is likely to be 'in his veins'; but if we say he is 'of the seed of Abraham' we feel something of the permanence and indestructibility of that germ which can be divided and scattered among all nations, but remains recognisable in type and characteristics after 4,000 years.

I knew a breeder who had a chest containing bottles of coloured liquids by which he used to illustrate the relationships of his dogs, pouring from one to another and titrating them quantitatively to illustrate their pedigrees. Galton was beset by the same kind of mistake when he promulgated his 'Law of Ancestral Heredity.' With modern

research all this has been cleared away. The allotment of characteristics among offspring is not accomplished by the exudation of drops of a tincture representing the sum of the characteristics of the parent organism, but by a process of *cell-division*, in which numbers of these characters, or rather the elements upon which they depend, are sorted out among the resulting germ-cells in an orderly fashion. What these elements, or *factors* as we call them, are we do not know. That they are in some way directly transmitted by the material of the ovum and of the spermatozoon is obvious, but it seems to me unlikely that they are in any simple or literal sense material particles. I suspect rather that their properties depend on some phenomenon of arrangement. However that may be, analytical breeding proves that it is according to the distribution of these genetic factors, to use a non-committal term, that the characters of the offspring are decided. The first business of experimental genetics is to determine their number and interactions, and then to make an analysis of the various types of life.

Now the ordinary genealogical trees, such as those which the stud-books provide in the case of the domestic animals, or the Heralds' College provides in the case of man, tell nothing of all this. Such methods of depicting descent cannot even show the one thing they are devised to show—purity of 'blood.' For at last we know the physiological meaning of that expression. An organism is pure-bred when it has been formed by the union in fertilisation of two germ-cells which are alike in the factors they bear; and since the factors for the several characteristics are independent of each other, this question of purity must be separately considered for each of them. A man, for example, may be pure-bred in respect of his musical ability and cross-bred in respect of the colour of his eyes or the shape of his mouth. Though we know nothing of the essential nature of these factors, we know a good deal of their powers. They may confer height, colour, shape, instincts, powers both of mind and body—indeed, so many of the attributes which animals and plants possess, that we feel justified in the expectation that with continued analysis they will be proved to be responsible for most if not all of the differences by which the varying individuals of any species are distinguished from each other. I will not assert that the greater differences which characterise distinct Species are due generally to such independent factors, but that is the conclusion to which the available evidence points. All this is now so well understood, and has been so often demonstrated and expounded, that details of evidence are now superfluous.

But for the benefit of those who are unfamiliar with such work let me briefly epitomise its main features and consequences. Since genetic factors are definite things, either present in or absent from any germ-cell, the individual may be either 'pure-bred' for any particular factor,

or its absence, if he is constituted by the union of two germ-cells both possessing or both destitute of that factor. If the individual is thus pure, all his germ-cells will in that respect be identical, for they are simply bits of the similar germ-cells which united in fertilisation to produce the parent organism. We thus reach the essential principle, that an organism cannot pass on to offspring a factor which it did not itself receive in fertilisation. Parents, therefore, which are both destitute of a given factor can only produce offspring equally destitute of it; and, on the contrary, parents both pure-bred for the presence of a factor produce offspring equally pure-bred for its presence. Whereas the germ-cells of the pure-bred are all alike, those of the cross-bred, which results from the union of dissimilar germ-cells, are mixed in character. Each positive factor segregates from its negative opposite, so that some germ-cells carry the factor and some do not. Once the factors have been identified by their effects, the average composition of the several kinds of families formed from the various matings can be predicted.

Only those who have themselves witnessed the fixed operations of these simple rules can feel their full significance. We come to look behind the simulacrum of the individual body, and we endeavour to disintegrate its features into the genetic elements by whose union the body was formed. Set out in cold general phrases such discoveries may seem remote from ordinary life. Become familiar with them and you will find your outlook on the world has changed. Watch the effects of segregation among the living things with which you have to do—plants, fowls, dogs, horses, that mixed concourse of humanity we call the English race, your friends' children, your own children, yourself—and however firmly imagination be restrained to the bounds of the known and the proved, you will feel something of that range of insight into Nature which Mendelism has begun to give. The question is often asked whether there are not also in operation systems of descent quite other than those contemplated by the Mendelian rules. I myself have expected such discoveries, but hitherto none have been plainly demonstrated. It is true we are often puzzled by the failure of a parental type to reappear in its completeness after a cross—the merino sheep or the fantail pigeon, for example. These exceptions may still be plausibly ascribed to the interference of a multitude of factors, a suggestion not easy to disprove; though it seems to me equally likely that segregation has been in reality imperfect. Of the descent of quantitative characters we still know practically nothing. These and hosts of difficult cases remain almost untouched. In particular the discovery of E. Baur, and the evidence of Winkler in regard to his 'graft hybrids,' both showing that the sub-epidermal layer of a plant—the layer from which the germ-cells are derived—may bear exclusively the characters

of a part only of the soma, give hints of curious complications, and suggest that in plants at least the interrelations between soma and gamete may be far less simple than we have supposed. Nevertheless, speaking generally, we see nothing to indicate that qualitative characters descend, whether in plants or animals, according to systems which are incapable of factorial representation.

The body of evidence accumulated by this method of analysis is now very large, and is still growing fast by the labours of many workers. Progress is also beginning along many novel and curious lines. The details are too technical for inclusion here. Suffice it to say that not only have we proof that segregation affects a vast range of characteristics, but in the course of our analysis phenomena of most unexpected kinds have been encountered. Some of these things twenty years ago must have seemed inconceivable. For example, the two sets of sex organs, male and female, of the same plant may not be carrying the same characteristics; in some animals characteristics, quite independent of sex, may be distributed solely or predominantly to one sex; in certain species the male may be breeding true to its own type, while the female is permanently mongrel, throwing off eggs of a distinct variety in addition to those of its own type; characteristics, essentially independent, may be associated in special combinations which are largely retained in the next generation, so that among the grandchildren there is numerical preponderance of those combinations which existed in the grandparents—a discovery which introduces us to a new phenomenon of polarity in the organism.

We are accustomed to the fact that the fertilised egg has a polarity, a front and hind end for example; but we have now to recognise that it, or the primitive germinal cells formed from it, may have another polarity shown in the groupings of the parental elements. I am entirely sceptical as to the occurrence of segregation solely in the maturation of the germ-cells,[4] preferring at present to regard it as a special case of that patchwork condition we see in so many plants. These mosaics may break up, emitting bud-sports at various cell-divisions, and I suspect that the great regularity seen in the F_2 ratios of the cereals, for example, is a consequence of very late segregation, whereas the excessive irregularity found in other cases may be taken to indicate that segregation can happen at earlier stages of differentiation.

The paradoxical descent of colour-blindness and other sex-limited conditions—formerly regarded as an inscrutable caprice of nature—has been represented with approximate correctness, and we already know something as to the way, or, perhaps, I should say ways, in which the

[4] The fact that in certain plants the male and female organs respectively carry distinct factors may be quoted as almost decisively negativing the suggestion that segregation is confined to the reduction division.

determination of sex is accomplished in some of the forms of life—though, I hasten to add, we have no inkling as to any method by which that determination may be influenced or directed. It is obvious that such discoveries have bearings on most of the problems, whether theoretical or practical, in which animals and plants are concerned. Permanence or change of type, perfection of type, purity or mixture of race, 'racial development,' the succession of forms, from being vague phrases expressing matters of degree, are now seen to be capable of acquiring physiological meanings, already to some extent assigned with precision. For the naturalist—and it is to him that I am especially addressing myself to-day—these things are chiefly significant as relating to the history of organic beings—the theory of Evolution, to use our modern name. They have, as I shall endeavour to show in my second address to be given in Sydney, an immediate reference to the conduct of human society.

I suppose that everyone is familiar in outline with the theory of the Origin of Species which Darwin promulgated. Through the last fifty years this theme of the Natural Selection of favoured races has been developed and expounded in writings innumerable. Favoured races certainly can replace others. The argument is sound, but we are doubtful of its value. For us that debate stands adjourned. We go to Darwin for his incomparable collection of facts. We would fain emulate his scholarship, his width and his power of exposition, but to us he speaks no more with philosophical authority. We read his scheme of Evolution as we would that of Lucretius or of Lamarck, delighting in their simplicity and their courage. The practical and experimental study of Variation and Heredity has not merely opened a new field; it has given a new point of view and new standards of criticism. Naturalists may still be found expounding teleological systems[5] which would have delighted Dr. Pangloss himself, but at the present time few are misled. The student of genetics knows that

[5] I take the following from the Abstract of a recent Croonian Lecture 'On the Origin of Mammals' delivered to the Royal Society:—'In Upper Triassic times the larger Cynodonts preyed upon the large Anomodont, *Kannemeyeria*, and carried on their existence so long as these Anomodonts survived, but died out with them about the end of the Trias or in Rhætic times. The small Cynodonts, having neither small Anomodonts nor small Cotylosaurs to feed on, were forced to hunt the very active long-limbed Thecodonts. The greatly increased activity brought about that series of changes which formed the mammals—the flexible skin with hair, the four-chambered heart and warm blood, the loose jaw with teeth for mastication, an increased development of tactile sensation and a great increase of cerebrum. Not improbably the attacks of the newly evolved Cynodont or mammalian type brought about a corresponding evolution in the Pseudosuchian Thecodonts, which ultimately resulted in the formation of Dinosaurs and Birds.' Broom, R., *Proc. Roy. Soc.* B., 87, p. 88.

the time for the development of theory is not yet. He would rather stick to the seed-pan and the incubator.

In face of what we now know of the distribution of variability in nature the scope claimed for Natural Selection in determining the fixity of Species must be greatly reduced. The doctrine of the survival of the fittest is undeniable so long as it is applied to the organism as a whole, but to attempt by this principle to find value in all definiteness of parts and functions, and in the name of Science to see fitness everywhere is mere eighteenth-century optimism. Yet it was in application to the parts, to the details of specific difference, to the spots on the peacock's tail, to the colouring of an Orchid flower, and hosts of such examples, that the potency of Natural Selection was urged with the strongest emphasis. Shorn of these pretensions the doctrine of the survival of favoured races is a truism, helping scarcely at all to account for the diversity of species. Tolerance plays almost as considerable a part. By these admissions almost the last shred of that teleological fustian with which Victorian philosophy loved to clothe the theory of Evolution is destroyed. Those who would proclaim that whatever is is right will be wise henceforth to base this faith frankly on the impregnable rock of superstition, and to abstain from direct appeals to natural fact.

My predecessor said last year that in physics the age is one of rapid progress and profound scepticism. In at least as high a degree this is true of Biology, and as a chief characteristic of modern evolutionary thought we must confess also to a deep but irksome humility in presence of great vital problems. Every theory of Evolution must be such as to accord with the facts of physics and chemistry, a primary necessity to which our predecessors paid small heed. For them the unknown was a rich mine of possibilities on which they could freely draw. For us it is rather an impenetrable mountain out of which the truth can be chipped in rare and isolated fragments. Of the physics and chemistry of life we know next to nothing. Somehow the characters of living things are bound up in properties of colloids, and are largely determined by the chemical powers of enzymes, but the study of these classes of matter has only just begun. Living things are found by a simple experiment to have powers undreamt of, and who knows what may be behind?

Naturally we turn aside from generalities. It is no time to discuss the origin of the Mollusca or of Dicotyledons, while we are not even sure how it came to pass that *Primula obconica* has in twenty-five years produced its abundant new forms almost under our eyes. Knowledge of heredity has so reacted on our conceptions of variation that very competent men are even denying that variation in the old sense is a genuine occurrence at all. Variation is postulated as the basis of all evolutionary change. Do we then as a matter of fact find in the world

about us variations occurring of such a kind as to warrant faith in a contemporary progressive Evolution? Till lately most of us would have said 'yes' without misgiving. We should have pointed, as Darwin did, to the immense range of diversity seen in many wild species, so commonly that the difficulty is to define the types themselves. Still more conclusive seemed the profusion of forms in the various domesticated animals and plants, most of them incapable of existing even for a generation in the wild state, and therefore fixed unquestionably by human selection. These, at least, for certain, are new forms, often distinct enough to pass for species, which has arisen by variation. But when analysis is applied to this mass of variation the matter wears a different aspect. Closely examined, what is the 'variability' of wild species? What is the natural fact which is denoted by the statement that a given species exhibits much variation? Generally one of two things: either that the individuals collected in one locality differ among themselves; or perhaps more often that samples from separate localities differ from each other. As direct evidence of variation it is clearly to the first of these phenomena that we must have recourse—the heterogeneity of a population breeding together in one area. This heterogeneity may be in any degree, ranging from slight differences that systematists would disregard, to a complex variability such as we find in some moths, where there is an abundance of varieties so distinct that many would be classified as specific forms but for the fact that all are freely breeding together. Naturalists formerly supposed that any of these varieties might be bred from any of the others. Just as the reader of novels is prepared to find that any kind of parents may have any kind of children in the course of the story, so was the evolutionist ready to believe that any pair of moths might produce any of the varieties included in the species. Genetic analysis has disposed of all these mistakes. We have no longer the smallest doubt that in all these examples the varieties stand in a regular descending order, and that they are simply terms in a series of combinations of factors separately transmitted, of which each may be present or absent.

The appearance of contemporary variability proves to be an illusion. Variation from step to step in the series must occur either by the addition or by the loss of a factor. Now, of the origin of new forms *by loss* there seems to me to be fairly clear evidence, but of the *contemporary acquisition* of any new factor I see no satisfactory proof, though I admit there are rare examples which may be so interpreted. We are left with a picture of variation utterly different from that which we saw at first. Variation now stands out as a definite physiological event. We have done with the notion that Darwin came latterly to favour, that large differences can arise by accumulation of small

differences. Such small differences are often mere ephemeral effects of conditions of life, and as such are not transmissible; but even small differences, when truly genetic, are factorial like the larger ones, and there is not the slightest reason for supposing that they are capable of summation. As to the origin or source of these positive separable factors, we are without any indication or surmise. By their effects we know them to be definite, as definite, say, as the organisms which produce diseases; but how they arise and how they come to take part in the composition of the living creature so that when present they are treated in cell-division as constituents of the germs, we cannot conjecture.

It was a commonplace of evolutionary theory that at least the domestic animals have been developed from a few wild types. Their origin was supposed to present no difficulty. The various races of fowl, for instance, all came from *Gallus bankiva*, the Indian jungle-fowl. So we are taught; but try to reconstruct the steps in their evolution and you realise your hopeless ignorance. To be sure there are breeds, such as Black-red Game and Brown Leghorns, which have the colours of the jungle-fowl, though they differ in shape and other respects. As we know so little as yet of the genetics of shape, let us assume that those transitions could be got over. Suppose, further, as is probable, that the absence of the maternal instinct in the Leghorn is due to loss of one factor which the jungle-fowl possesses. So far we are on fairly safe ground. But how about White Leghorns? Their origin may seem easy to imagine, since white varieties have often arisen in well-authenticated cases. But the white of White Leghorns is not, as white in nature often is, due to the loss of the colour-elements, but to the action of something which inhibits their expression. Whence did that something come? The same question may be asked respecting the heavy breeds, such as Malays or Indian Game. Each of these is a separate introduction from the East. To suppose that these, with their peculiar combs and close feathering, could have been developed from pre-existing European breeds is very difficult. On the other hand, there is no wild species now living any more like them. We may, of course, postulate that there was once such a species, now lost. That is quite conceivable, though the suggestion is purely speculative. I might thus go through the list of domesticated animals and plants of ancient origin and again and again we should be driven to this suggestion, that many of their distinctive characters must have been derived from some wild original now lost. Indeed, to this unsatisfying conclusion almost every careful writer on such subjects is now reduced. If we turn to modern evidence the case looks even worse. The new breeds of domestic animals made in recent times are the carefully selected products of recombination of pre-existing breeds. Most of the

new varieties of cultivated plants are the outcome of deliberate crossing. There is generally no doubt in the matter. We have pretty full histories of these crosses in Gladiolus, Orchids, Cineraria, Begonia, Calceolaria, Pelargonium, &c. A very few certainly arise from a single origin. The Sweet Pea is the clearest case, and there are others which I should name with hesitation. The Cyclamen is one of them, but we know that efforts to cross Cyclamens were made early in the cultural history of the plant, and they may very well have been successful. Several plants for which single origins are alleged, such as the Chinese Primrose, the Dahlia, and Tobacco, came to us in an already domesticated state, and their origins remain altogether mysterious. Formerly single origins were generally presumed, but at the present time numbers of the chief products of domestication, dogs, horses, cattle, sheep, poultry, wheat, oats, rice, plums, cherries, have in turn been accepted as 'polyphyletic,' or, in other words, derived from several distinct forms. The reason that has led to these judgments is that the distinctions between the chief varieties can be traced as far back as the evidence reaches, and that these distinctions are so great, so far transcending anything that we actually know variation capable of effecting, that it seems pleasanter to postpone the difficulty, relegating the critical differentiation to some misty antiquity into which we shall not be asked to penetrate. For it need scarcely be said that this is mere procrastination. If the origin of a form under domestication is hard to imagine, it becomes no easier to conceive of such enormous deviations from type coming to pass in the wild state. Examine any two thoroughly distinct species which meet each other in their distribution, as, for instance, *Lychnis diurna* and *vespertina* do. In areas of overlap are many intermediate forms. These used to be taken to be transitional steps, and the specific distinctness of *vespertina* and *diurna* was on that account questioned. Once it is known that these supposed intergrades are merely mongrels between the two species the transition from one to the other is practically beyond our powers of imagination to conceive. If both these can survive, why has their common parent perished? Why when they cross do they not reconstruct it instead of producing partially sterile hybrids? I take this example to show how entirely the facts were formerly misinterpreted.

When once the idea of a true-breeding—or, as we say, homozygous—type is grasped, the problem of variation becomes an insistent oppression. What can make such a type vary? We know, of course, one way by which novelty can be introduced—by crossing. Cross two well-marked varieties—for instance, of Chinese Primula—each breeding true, and in the second generation by mere recombination of the various factors which the two parental types severally introduced, there will be a profusion of forms, utterly unlike each other, distinct also from

the original parents. Many of these can be bred true, and if found wild would certainly be described as good species. Confronted by the difficulty I have put before you, and contemplating such amazing polymorphism in the second generation from a cross in *Antirrhinum*, Lotsy has lately with great courage suggested to us that all variation may be due to such crossing. I do not disguise my sympathy with this effort. After the blind complacency of conventional evolutionists it is refreshing to meet so frank an acknowledgment of the hardness of the problem. Lotsy's utterance will at least do something to expose the artificiality of systematic zoology and botany. Whatever might or might not be revealed by experimental breeding, it is certain that without such tests we are merely guessing when we profess to distinguish specific limits and to declare that this is a species and that a variety. The only definable unit in classification is the homozygous form which breeds true. When we presume to say that such and such differences are trivial and such others valid, we are commonly embarking on a course for which there is no physiological warrant. Who could have foreseen that the Apple and the Pear—so like each other that their botanical differences are evasive—could not be crossed together, though species of Antirrhinum so totally unlike each other as *majus* and *molle* can be hybridized, as Baur has shown, without a sign of impaired fertility? Jordan was perfectly right. The true-breeding forms which he distinguished in such multitudes are real entities, though the great systematists, dispensing with such laborious analysis, have pooled them into arbitrary Linnean species, for the convenience of collectors and for the simplification of catalogues. Such pragmatical considerations may mean much in the museum, but with them the student of the physiology of variation has nothing to do. These 'little species,' finely cut, true-breeding, and innumerable mongrels between them, are what he finds when he examines any so-called variable type. On analysis the semblance of variability disappears, and the illusion is shown to be due to segregation and recombination of series of factors on pre-determined lines. As soon as the 'little species' are separated out they are found to be fixed. In face of such a result we may well ask with Lotsy, is there such a thing as spontaneous variation anywhere? His answer is that there is not.

Abandoning the attempt to show that positive factors can be added to the original stock, we have further to confess that we cannot often actually prove variation by loss of factor to be a real phenomenon. Lotsy doubts whether even this phenomenon occurs. The sole source of variation, in his view, is crossing. But here I think he is on unsafe ground. When a well-established variety like 'Crimson King' Primula, bred by Messrs. Sutton in thousands of individuals, gives off, as it did a few years since, a salmon-coloured

variety, 'Coral King,' we might claim this as a genuine example of variation by loss. The new variety is a simple recessive. It differs from 'Crimson King' only in one respect, the loss of a single colour-factor, and, of course, bred true from its origin. To account for the appearance of such a new form by any process of crossing is exceedingly difficult. From the nature of the case there can have been no cross since 'Crimson King' was established, and hence the salmon must have been concealed as a recessive from the first origin of that variety, even when it was represented by very few individuals, probably only by a single one. Surely, if any of these had been heterozygous for salmon this recessive could hardly have failed to appear during the process of self-fertilisation by which the stock would be multiplied, even though that selfing may not have been strictly carried out. Examples like this seem to me practically conclusive.[6] They can be challenged, but not, I think, successfully. Then again in regard to those variations in number and division of parts which we call meristic, the reference of these to original cross-breeding is surely barred by the circumstances in which they often occur. There remain also the rare examples mentioned already in which a single wild origin may with much confidence be assumed. In spite of repeated trials, no one has yet succeeded in crossing the Sweet Pea with any other leguminous species. We know that early in its cultivated history it produced at least two marked varieties which I can only conceive of as spontaneously arising, though, no doubt, the profusion of forms we now have was made by the crossing of those original varieties. I mention the Sweet Pea thus prominently for another reason, that it introduces us to another though subsidiary form of variation, which may be described as a *fractionation* of factors. Some of my Mendelian colleagues have spoken of genetic factors as permanent and indestructible. Relative permanence in a sense they have, for they commonly come out unchanged after segregation. But I am satisfied that they may occasionally undergo a quantitative disintegration, with the consequence that varieties are produced intermediate between the integral varieties from which they were derived. These disintegrated conditions I have spoken of as subtraction—or reduction—stages. For example, the Picotee Sweet Pea, with its purple edges, can surely be nothing but a condition produced by the factor which ordinarily makes the fully purple flower, quantitatively diminished. The pied animal, such as the Dutch rabbit, must similarly be regarded as the result of partial defect of the chromogen from which the pigment is formed, or conceivably of the factor which effects its oxidation. On such lines I think we may with great confidence

[6] The numerous and most interesting 'mutations' recorded by Professor T. H. Morgan and his colleagues in the fly, *Drosophila*, may also be cited as unexceptionable cases.

interpret all those intergrading forms which breed true and are not produced by factorial interference.

It is to be inferred that these fractional degradations are the consequence of irregularities in segregation. We constantly see irregularities in the ordinary meristic processes, and in the distribution of somatic differentiation. We are familiar with half segments, with imperfect twinning, with leaves partially petaloid, with petals partially sepaloid. All these are evidences of departures from the normal regularity in the rhythms of repetition, or in those waves of differentiation by which the qualities are sorted out among the parts of the body. Similarly, when in segregation the qualities are sorted out among the germ-cells in certain critical cell-divisions, we cannot expect these differentiating divisions to be exempt from the imperfections and irregularities which are found in all the grosser divisions that we can observe. If I am right, we shall find evidence of these irregularities in the association of unconformable numbers with the appearance of the novelties which I have called fractional. In passing let us note how the history of the Sweet Pea belies those ideas of a continuous evolution with which we had formerly to contend. The big varieties came first. The little ones have arisen later, as I suggest by fractionation. Presented with a collection of modern Sweet Peas how prettily would the devotees of Continuity have arranged them in a graduated series, showing how every intergrade could be found, passing from the full colour of the wild Sicilian species in one direction to white, in the other to the deep purple of 'Black Prince,' though happily we know these two to be among the earliest to have appeared.

Having in view these and other considerations which might be developed, I feel no reasonable doubt that though we may have to forgo a claim to variations by addition of factors, yet variation both by loss of factors and by fractionation of factors is a genuine phenomenon of contemporary nature. If then we have to dispense, as seems likely, with any addition from without we must begin seriously to consider whether the course of Evolution can at all reasonably be represented as an unpacking of an original complex which contained within itself the whole range of diversity which living things present. I do not suggest that we should come to a judgment as to what is or is not probable in these respects. As I have said already, this is no time for devising theories of Evolution, and I propound none. But as we have got to recognise that there has been an Evolution, that somehow or other the forms of life have arisen from fewer forms, we may as well see whether we are limited to the old view that evolutionary progress is from the simple to the complex, and whether after all it is conceivable that the process was the other way about. When the facts of genetic discovery become familiarly known to biologists, and cease to be the preoccupa-

tion of a few, as they still are, many and long discussions must inevitably arise on the question, and I offer these remarks to prepare the ground. I ask you simply to open your minds to this possibility. It involves a certain effort. We have to reverse our habitual modes of thought. At first it may seem rank absurdity to suppose that the primordial form or forms of protoplasm could have contained complexity enough to produce the divers types of life. But is it easier to imagine that these powers could have been conveyed by extrinsic additions? Of what nature could these additions be? Additions of material cannot surely be in question. We are told that salts of iron in the soil may turn a pink hydrangea blue. The iron cannot be passed on to the next generation. How can the iron multiply itself? The power to assimilate the iron is all that can be transmitted. A disease-producing organism like the pebrine of silkworms can in a very few cases be passed on through the germ-cells. Such an organism can multiply and can produce its characteristic effects in the next generation. But it does not become part of the invaded host, and we cannot conceive it taking part in the geometrically ordered processes of segregation. These illustrations may seem too gross; but what refinement will meet the requirements of the problem, that the thing introduced must be, as the living organism itself is, capable of multiplication and of subordinating itself in a definite system of segregation? That which is conferred in variation must rather itself be a change, not of material, but of arrangement, or of motion. The invocation of additions extrinsic to the organism does not seriously help us to imagine how the power to change can be conferred, and if it prove that hope in that direction must be abandoned, I think we lose very little. By the re-arrangement of a very moderate number of things we soon reach a number of possibilities practically infinite.

That primordial life may have been of small dimensions need not disturb us. Quantity is of no account in these considerations. Shakespeare once existed as a speck of protoplasm not so big as a small pin's head. To this nothing was added that would not equally well have served to build up a baboon or a rat. Let us consider how far we can get by the process of removal of what we call 'epistatic' factors, in other words those that control, mask, or suppress underlying powers and faculties. I have spoken of the vast range of colours exhibited by modern Sweet Peas. There is no question that these have been derived from the one wild bi-colour form by a process of successive removals. When the vast range of form, size, and flavour to be found among the cultivated apples is considered it seems difficult to suppose that all this variety is hidden in the wild crab-apple. I cannot positively assert that this is so, but I think all familiar with Mendelian analysis would agree with me that it is probable, and that the wild crab contains presumably

inhibiting elements which the cultivated kinds have lost. The legend that the seedlings of cultivated apples become crabs is often repeated. After many inquiries among the raisers of apple seedlings I have never found an authentic case—once only even an alleged case, and this on inquiry proved to be unfounded. I have confidence that the artistic gifts of mankind will prove to be due not to something added to the make-up of an ordinary man, but to the absence of factors which in the normal person inhibit the development of these gifts. They are almost beyond doubt to be looked upon as *releases* of powers normally suppressed. The instrument is there, but it is 'stopped down.' The scents of flowers or fruits, the finely repeated divisions that give its quality to the wool of the Merino, or in an analogous case the multiplicity of quills to the tail of the fantail pigeon, are in all probability other examples of such releases. You may ask what guides us in the discrimination of the positive factors and how we can satisfy ourselves that the appearance of a quality is due to loss. It must be conceded that in these determinations we have as yet recourse only to the effects of dominance. When the tall pea is crossed with the dwarf, since the offspring is tall we say that the tall parent passed a factor into the cross-bred which makes it tall. The pure tall parent had two doses of this factor; the dwarf had none; and since the cross-bred is tall we say that one dose of the dominant tallness is enough to give the full height. The reasoning seems unanswerable. But the commoner result of crossing is the production of a form intermediate between the two pure parental types. In such examples we see clearly enough that the full parental characteristics can only appear when they are homozygous—formed from similar germ-cells, and that one dose is insufficient to produce either effect fully. When this is so we can never be sure which side is positive and which negative. Since, then, when dominance is incomplete we find ourselves in this difficulty, we perceive that the amount of the effect is our only criterion in distinguishing the positive from the negative, and when we return even to the example of the tall and dwarf peas the matter is not so certain as it seemed. Professor Cockerell lately found among thousands of yellow sunflowers one which was partly red. By breeding he raised from this a form wholly red. Evidently the yellow and the wholly red are the pure forms, and the partially red is the heterozygote. We may then say that the yellow is YY with two doses of a positive factor which inhibits the development of pigment; the red is yy, with no dose of the inhibitor; and the partially red are Yy, with only one dose of it. But we might be tempted to think the red was a positive characteristic, and invert the expressions, representing the red as RR, the partly red as Rr, and the yellow as rr. According as we adopt the one or the other system of expression we shall interpret the evolutionary change as one of loss or as one of

addition. May we not interpret the other apparent new dominants in the same way? The white dominant in the fowl or in the Chinese Primula can inhibit colour. But may it not be that the original coloured fowl or Primula had two doses of a factor which inhibited this inhibitor? The Pepper-Moth, *Amphidasys betularia*, produced in England about 1840 a black variety, then a novelty, now common in certain areas, which behaves as a full dominant. The pure blacks are no blacker than the cross-bred. Though at first sight it seems that the black *must* have been something added, we can without absurdity suggest that the normal is the term in which two doses of inhibitor are present, and that in the absence of one of them the black appears.

In spite of seeming perversity, therefore, we have to admit that there is no evolutionary change which in the present state of our knowledge we can positively declare to be not due to loss. When this has been conceded it is natural to ask whether the removal of inhibiting factors may not be invoked in alleviation of the necessity which has driven students of the domestic breeds to refer their diversities to multiple origins. Something, no doubt, is to be hoped for in that direction, but not until much better and more extensive knowledge of what variation by loss may effect in the living body can we have any real assurance that this difficulty has been obviated. We should be greatly helped by some indication as to whether the origin of life has been single or multiple. Modern opinion is, perhaps, inclining to the multiple theory, but we have no real evidence. Indeed, the problem still stands outside the range of scientific investigation, and when we hear the spontaneous formation of formaldehyde mentioned as a possible first step in the origin of life, we think of Harry Lauder in the character of a Glasgow schoolboy pulling out his treasures from his pocket—'That's a wassher—for makkin' motor cars'!

As the evidence stands at present all that can be safely added in amplification of the evolutionary creed may be summed up in the statement that variation occurs as a definite event often producing a sensibly discontinuous result; that the succession of varieties comes to pass by the elevation and establishment of sporadic groups of individuals owing their origin to such isolated events; and that the change which we see as a nascent variation is often, perhaps always, one of loss. Modern research lends not the smallest encouragement or sanction to the view that gradual evolution occurs by the transformation of masses of individuals, though that fancy has fixed itself on popular imagination. The isolated events to which variation is due are evidently changes in the germinal tissues, probably in the manner in which they divide. It is likely that the occurrence of these variations is wholly irregular, and as to their causation we are absolutely without surmise or even plausible speculation. Distinct types once arisen, no

doubt a profusion of the forms called species have been derived from them by simple crossing and subsequent recombination. New species may be now in course of creation by this means, but the limits of the process are obviously narrow. On the other hand, we see no changes in progress around us in the contemporary world which we can imagine likely to culminate in the evolution of forms distinct in the larger sense. By intercrossing dogs, jackals, and wolves new forms of these types can be made, some of which may be species, but I see no reason to think that from such material a fox could be bred in indefinite time, or that dogs could be bred from foxes.

Whether Science will hereafter discover that certain groups can by peculiarities in their genetic physiology be declared to have a prerogative quality justifying their recognition as species in the old sense, and that the differences of others are of such a subordinate degree that they may in contrast be termed varieties, further genetic research alone can show. I myself anticipate that such a discovery will be made, but I cannot defend the opinion with positive conviction.

Somewhat reluctantly, and rather from a sense of duty, I have devoted most of this Address to the evolutionary aspects of genetic research. We cannot keep these things out of our heads, though sometimes we wish we could. The outcome, as you will have seen, is negative, destroying much that till lately passed for gospel. Destruction may be useful, but it is a low kind of work. We are just about where Boyle was in the seventeenth century. We can dispose of Alchemy, but we cannot make more than a quasi-chemistry. We are awaiting our Priestley and our Mendeléeff. In truth it is not these wider aspects of genetics that are at present our chief concern. They will come in their time. The great advances of science are made like those of evolution, not by imperceptible mass-improvement, but by the sporadic birth of penetrative genius. The journeymen follow after him, widening and clearing up, as we are doing along the track that Mendel found.

Part II.—SYDNEY.[7]

At Melbourne I spoke of the new knowledge of the properties of living things which Mendelian analysis has brought us. I indicated how these discoveries are affecting our outlook on that old problem of natural history, the origin and nature of Species, and the chief conclusion I drew was the negative one, that, though we must hold to our faith in the Evolution of Species, there is little evidence as to how it has come about, and no clear proof that the process is continuing in any considerable degree at the present time. The thought

[7] Delivered in Sydney on Thursday, August 20, 1914.

uppermost in our minds is that knowledge of the nature of life is altogether too slender to warrant speculation on these fundamental subjects. Did we presume to offer such speculations they would have no more value than those which alchemists might have made as to the nature of the elements. But though in regard to these theoretical aspects we must confess to such deep ignorance, enough has been learnt of the general course of heredity within a single species to justify many practical conclusions which cannot in the main be shaken. I propose now to develop some of these conclusions in regard to our own species, Man.

In my former Address I mentioned the condition of certain animals and plants which are what we call 'polymorphic.' Their populations consist of individuals of many types, though they breed freely together with perfect fertility. In cases of this kind which have been sufficiently investigated it has been found that these distinctions—sometimes very great and affecting most diverse features of organisation—are due to the presence or absence of elements, or factors as we call them, which are treated in heredity as separate entities. These factors and their combinations produce the characteristics which we perceive. No individual can acquire a particular characteristic unless the requisite factors entered into the composition of that individual at fertilisation, being received either from the father or from the mother or from both, and consequently no individual can pass on to his offspring positive characters which he does not himself possess. Rules of this kind have already been traced in operation in the human species; and though I admit that an assumption of some magnitude is involved when we extend the application of the same system to human characteristics in general, yet the assumption is one which I believe we are fully justified in making. With little hesitation we can now declare that the potentialities and aptitudes, physical as well as mental, sex, colours, powers of work or invention, liability to diseases, possible duration of life, and the other features by which the members of a mixed population differ from each other, are determined from the moment of fertilisation; and by all that we know of heredity in the forms of life with which we can experiment we are compelled to believe that these qualities are in the main distributed on a factorial system. By changes in the outward conditions of life the expression of some of these powers and features may be excited or restrained. For the development of some an external opportunity is needed, and if that be withheld the character is never seen, any more than if the body be starved can the full height be attained; but such influences are superficial and do not alter the genetic constitution.

The factors which the individual receives from his parents and no others are those which he can transmit to his offspring; and if a factor

was received from one parent only, not more than half the offspring, on an average, will inherit it. What is it that has so long prevented mankind from discovering such simple facts? Primarily the circumstance that as man must have *two* parents it is not possible quite easily to detect the contributions of each. The individual body is a *double* structure, whereas the germ-cells are *single*. Two germ-cells unite to produce each individual body, and the ingredients they respectively contribute interact in ways that leave the ultimate product a medley in which it is difficult to identify the several ingredients. When, however, their effects are conspicuous the task is by no means impossible. In part also even physiologists have been blinded by the survival of ancient and obscurantist conceptions of the nature of man by which they were discouraged from the application of any rigorous analysis. Medical literature still abounds with traces of these archaisms, and, indeed, it is only quite recently that prominent horse-breeders have come to see that the dam matters as much as the sire. For them, though vast pecuniary considerations were involved, the old 'homunculus' theory was good enough. We were amazed at the notions of genetic physiology which Professor Baldwin Spencer encountered in his wonderful researches among the natives of Central Australia; but in truth, if we reflect that these problems have engaged the attention of civilised man for ages, the fact that he, with all his powers of recording and deduction, failed to discover any part of the Mendelian system is almost as amazing. The popular notion that any parents can have any kind of children within the racial limits is contrary to all experience, yet we have gravely entertained such ideas. As I have said elsewhere, the truth might have been found out at any period in the world's history if only pedigrees had been drawn the right way up. If, instead of exhibiting the successive pairs of progenitors who have contributed to the making of an ultimate individual, some one had had the idea of setting out the posterity of a single ancestor who possessed a marked feature such as the Habsburg lip, and showing the transmission of this feature along some of the descending branches and the permanent loss of the feature in collaterals, the essential truth that heredity can be expressed in terms of presence and absence must have at once become apparent. For the descendant is not, as he appears in the conventional pedigree, a sort of pool into which each tributary ancestral stream has poured something, but rather a conglomerate of ingredient-characters taken from his progenitors in such a way that some ingredients are represented and others are omitted.

Let me not, however, give the impression that the unravelling of such descents is easy. Even with fairly full details, which in the case of man are very rarely to be had, many complications occur, often preventing us from obtaining more than a rough general indication of

the system of descent. The nature of these complications we partly understand from our experience of animals and plants which are amenable to breeding under careful restrictions, and we know that they are mostly referable to various effects of interaction between factors by which the presence of some is masked.

Necessarily the clearest evidence of regularity in the inheritance of human characteristics has been obtained in regard to the descent of marked abnormalities of structure and congenital diseases. Of the descent of ordinary distinctions such as are met with in the normal healthy population we know little for certain. Hurst's evidence, that two parents both with light-coloured eyes—in the strict sense, meaning that no pigment is present on the front of the iris—do not have dark-eyed children, still stands almost alone in this respect. With regard to the inheritance of other colour-characteristics some advance has been made, but everything points to the inference that the genetics of colour and many other features in man will prove exceptionally complex. There are, however, plenty of indications of system comparable with those which we trace in various animals and plants, and we are assured that to extend and clarify such evidence is only a matter of careful analysis. For the present, in asserting almost any general rules for human descent, we do right to make large reservations for possible exceptions. It is tantalising to have to wait, but of the ultimate result there can be no doubt.

I spoke of complications. Two of these are worth illustrating here, for probably both of them play a great part in human genetics. It was discovered by Nilsson-Ehle, in the course of experiments with certain wheats, that several factors having the same power may co-exist in the same individual. These cumulative factors do not necessarily produce a cumulative effect, for any one of them may suffice to give the full result. Just as the pure-bred tall pea with its two factors for tallness is no taller than the cross-bred with a single factor, so these wheats with three pairs of factors for red colour are no redder than the ordinary reds of the same family. Similar observations have been made by East and others. In some cases, as in the Primulas studied by Gregory, the effect is cumulative. These results have been used with plausibility by Davenport and the American workers to elucidate the curious case of the mulatto. If the descent of colour in the cross between the negro and the white man followed the simplest rule, the offspring of two first-cross mulattos would be, on an average, one black: two mulattos: one white, but this is notoriously not so. Evidence of some segregation is fairly clear, and the deficiency of real whites may perhaps be accounted for on the hypothesis of cumulative factors, though by the nature of the case strict proof is not to be had. But at present I own to a preference for regarding such examples as

instances of imperfect segregation. The series of germ-cells produced by the cross-bred consists of some with no black, some with full black, and others with intermediate quantities of black. No statistical tests of the condition of the gametes in such cases exist, and it is likely that by choosing suitable crosses all sorts of conditions may be found, ranging from the simplest case of total segregation, in which there are only two forms of gametes, up to those in which there are all intermediates in various proportions. This at least is what general experience of hybrid products leads me to anticipate. Segregation is somehow effected by the rhythms of cell-division, if such an expression may be permitted. In some cases the whole factor is so easily separated that it is swept out at once; in others it is so intermixed that gametes of all degrees of purity may result. That is admittedly a crude metaphor, but as yet we cannot substitute a better. Be all this as it may, there are many signs that in human heredity phenomena of this kind are common, whether they indicate a multiplicity of cumulative factors or imperfections in segregation. Such phenomena, however, in no way detract from the essential truths that segregation occurs, and that the organism cannot pass on a factor which it has not itself received.

In human heredity we have found some examples, and I believe that we shall find many more, in which the descent of factors is limited by sex. The classical instances are those of colour-blindness and hæmophilia. Both these conditions occur with much greater frequency in males than in females. Of colour-blindness at least we know that the *sons* of the colour-blind man do not inherit it (unless the mother is a transmitter) and do not transmit it to their children of either sex. Some, probably all, of the daughters of the colour-blind father inherit the character, and though not themselves colour-blind, they transmit it to some (probably, on an average, half) of their offspring of both sexes. For since these normal-sighted women have only received the colour-blindness from one side of their parentage, only half their offspring, on an average, can inherit it. The sons who inherit the colour-blindness will be colour-blind, and the inheriting daughters become themselves again transmitters. Males with normal colour-vision, whatever their own parentage, do not have colour-blind descendants, unless they marry transmitting women. There are points still doubtful in the interpretation, but the critical fact is clear, that the germ-cells of the colour-blind man are of two kinds: (i) those which do not carry on the affection and are destined to take part in the formation of sons; and (ii) those which do carry on the colour-blindness and are destined to form daughters. There is evidence that the ova also are similarly predestined to form one or other of the sexes, but to discuss the whole question of sex-determination is beyond my present scope. The descent of these sex-limited affections never-

theless calls for mention here, because it is an admirable illustration of factorial predestination. It moreover exemplifies that *parental polarity* of the zygote to which I alluded in my first Address, a phenomenon which we suspect to be at the bottom of various anomalies of heredity, and suggests that there may be truth in the popular notion that in some respects sons resemble their mothers and daughters their fathers.

As to the descent of hereditary diseases and malformations, however, we have abundant data for deciding that many are transmitted as dominants and a few as recessives. The most remarkable collection of these data is to be found in family histories of diseases of the eye. Neurology and dermatology have also contributed many very instructive pedigrees. In great measure the ophthalmological material was collected by Edward Nettleship, for whose death we so lately grieved. After retiring from practice as an oculist he devoted several years to this most laborious task. He was not content with hearsay evidence, but travelled incessantly, personally examining all accessible members of the families concerned, working in such a way that his pedigrees are models of orderly observation and recording. His zeal stimulated many younger men to take part in the work, and it will now go on, with the result that the systems of descent of all the common hereditary diseases of the eye will soon be known with approximate accuracy.

Give a little imagination to considering the chief deduction from this work. Technical details apart, and granting that we cannot wholly interpret the numerical results, sometimes noticeably more and sometimes fewer descendants of these patients being affected than Mendelian formulæ would indicate, the expectation is that in the case of many diseases of the eye a large proportion of the children, grand-children, and remoter descendants of the patients will be affected with the disease. Sometimes it is only defective sight that is transmitted; in other cases it is blindness, either from birth or coming on at some later age. The most striking example perhaps is that of a form of night-blindness still prevalent in a district near Montpellier, which has affected at least 130 persons, all descending from a single affected individual [8] who came into the country in the seventeenth century. The transmission is in every case through an affected parent, and no normal has been known to pass on the condition. Such an example well serves to illustrate the fixity of the rules of descent. Similar instances might be recited relating to a great variety of other conditions, some trivial, others grave.

[8] The first human descent proved to follow Mendelian rules was that of a serious malformation of the hand studied by Farabee in America. Drinkwater subsequently worked out pedigrees for the same malformation in England. After many attempts, he now tells me that he has succeeded in proving that the American family and one of his own had an abnormal ancestor in common, five generations ago.

At various times it has been declared that men are born equal, and that the inequality is brought about by unequal opportunities. Acquaintance with the pedigrees of disease soon shows the fatuity of such fancies. The same conclusion, we may be sure, would result from the true representation of the descent of any human faculty. Never since Galton's publications can the matter have been in any doubt. At the time he began to study family histories even the broad significance of heredity was frequently denied, and resemblances to parents or ancestors were looked on as interesting curiosities. Inveighing against hereditary political institutions, Tom Paine remarks that the idea is as absurd as that of an 'hereditary wise man,' or an 'hereditary mathematician,' and to this day I suppose many people are not aware that he is saying anything more than commonly foolish. We, on the contrary, would feel it something of a puzzle if two parents, both mathematically gifted, had any children *not* mathematicians. Galton first demonstrated the overwhelming importance of these considerations, and had he not been misled, partly by the theory of pangenesis, but more by his mathematical instincts and training, which prompted him to apply statistical treatment rather than qualitative analysis, he might, not improbably, have discovered the essential facts of Mendelism.

It happens rarely that science has anything to offer to the common stock of ideas at once so comprehensive and so simple that the courses of our thoughts are changed. Contributions to the material progress of mankind are comparatively frequent. They result at once in application. Transit is quickened; communication is made easier; the food-supply is increased and population multiplied. By direct application to the breeding of animals and plants such results must even flow from Mendel's work. But I imagine the greatest practical change likely to ensue from modern genetic discovery will be a quickening of interest in the true nature of man and in the biology of races. I have spoken cautiously as to the evidence for the operation of any simple Mendelian system in the descent of human faculty; yet the certainty that systems which differ from the simpler schemes only in degree of complexity are at work in the distribution of characters among the human population cannot fail to influence our conceptions of life and of ethics, leading perhaps ultimately to modification of social usage. That change cannot but be in the main one of simplification. The eighteenth century made great pretence of a return to nature, but it did not occur to those philosophers first to inquire what nature is; and perhaps not even the patristic writings contain fantasies much further from physiological truth than those which the rationalists of the 'Encyclopædia' adopted as the basis of their social schemes. For men are so far from being born equal or similar that to the naturalist

they stand as the very type of a polymorphic species. Even most of our local races consist of many distinct strains and individual types. From the population of any ordinary English town as many distinct human breeds could in a few generations be isolated as there are now breeds of dogs, and indeed such a population in its present state is much what the dogs of Europe would be in ten years' time but for the interference of the fanciers. Even as at present constituted, owing to the isolating effects of instinct, fashion, occupation, and social class, many incipient strains already exist.

In one respect civilised man differs from all other species of animal or plant in that, having prodigious and ever-increasing power over nature, he invokes these powers for the preservation and maintenance of many of the inferior and all the defective members of his species. The inferior freely multiply, and the defective, if their defects be not so grave as to lead to their detention in prisons or asylums, multiply also without restraint. Heredity being strict in its action, the consequences are in civilised countries much what they would be in the kennels of the dog-breeder who continued to preserve all his puppies, good and bad: the proportion of defectives increases. The increase is so considerable that outside every great city there is a smaller town inhabited by defectives and those who wait on them. Round London we have a ring of such towns with some 30,000 inhabitants, of whom about 28,000 are defective, largely, though of course by no means entirely, bred from previous generations of defectives. Now, it is not for us to consider practical measures. As men of science we observe natural events and deduce conclusions from them. I may perhaps be allowed to say that the remedies proposed in America, in so far as they aim at the eugenic regulation of marriage on a comprehensive scale, strike me as devised without regard to the needs either of individuals or of a modern State. Undoubtedly if they decide to breed their population of one uniform puritan grey, they can do it in a few generations; but I doubt if timid respectability will make a nation happy, and I am sure that qualities of a different sort are needed if it is to compete with more vigorous and more varied communities. Everyone must have a preliminary sympathy with the aims of eugenists both abroad and at home. Their efforts at the least are doing something to discover and spread truth as to the physiological structure of society. The spirit of such organisations, however, almost of necessity suffers from a bias towards the accepted and the ordinary, and if they had power it would go hard with many ingredients of Society that could be ill-spared. I notice an ominous passage in which even Galton, the founder of eugenics, feeling perhaps some twinge of his Quaker ancestry, remarks that 'as the Bohemianism in the nature of our race is destined to perish, the sooner it goes, the happier for

mankind.' It is not the eugenists who will give us what Plato has called divine releases from the common ways. If some fancier with the catholicity of Shakespeare would take us in hand, well and good; but I would not trust even Shakespeares meeting as a committee. Let us remember that Beethoven's father was an habitual drunkard and that his mother died of consumption. From the genealogy of the patriarchs also we learn—what may very well be the truth—that the fathers of such as dwell in tents, and of all such as handle the harp or organ, and the instructor of every artificer in brass and iron—the founders, that is to say, of the arts and the sciences—came in direct descent from Cain, and not in the posterity of the irreproachable Seth, who is to us, as he probably was also in the narrow circle of his own contemporaries, what naturalists call a *nomen nudum*.

Genetic research will make it possible for a nation to elect by what sort of beings it will be represented not very many generations hence, much as a farmer can decide whether his byres shall be full of short-horns or Herefords. It will be very surprising indeed if some nation does not make trial of this new power. They may make awful mistakes, but I think they will try.

Whether we like it or not, extraordinary and far-reaching changes in public opinion are coming to pass. Man is just beginning to know himself for what he is—a rather long-lived animal, with great powers of enjoyment if he does not deliberately forgo them. Hitherto superstition and mythical ideas of sin have predominantly controlled these powers. Mysticism will not die out: for those strange fancies knowledge is no cure; but their forms may change, and mysticism as a force for the suppression of joy is happily losing its hold on the modern world. As in the decay of earlier religions Ushabti dolls were substituted for human victims, so telepathy, necromancy, and other harmless toys take the place of eschatology and the inculcation of a ferocious moral code. Among the civilised races of Europe we are witnessing an emancipation from traditional control in thought, in art, and in conduct which is likely to have prolonged and wonderful influences. Returning to freer or, if you will, simpler conceptions of life and death, the coming generations are determined to get more out of this world than their forefathers did. Is it then to be supposed that when science puts into their hand means for the alleviation of suffering immeasurable, and for making this world a happier place, that they will demur to using those powers? The intenser struggle between communities is only now beginning, and with the approaching exhaustion of that capital of energy stored in the earth before man began it must soon become still more fierce. In England some of our great-grandchildren will see the end of the easily accessible coal, and, failing some miraculous discovery of available energy, a wholesale

reduction in population. There are races who have shown themselves able at a word to throw off all tradition and take into their service every power that science has yet offered them. Can we expect that they, when they see how to rid themselves of the ever-increasing weight of a defective population, will hesitate? The time cannot be far distant when both individuals and communities will begin to think in terms of biological fact, and it behoves those who lead scientific thought carefully to consider whither action should lead. At present I ask you merely to observe the facts. The powers of science to preserve the defective are now enormous. Every year these powers increase. This course of action must reach a limit. To the deliberate intervention of civilisation for the preservation of inferior strains there must sooner or later come an end, and before long nations will realise the responsibility they have assumed in multiplying these 'cankers of a calm world and a long peace.'

The definitely feeble-minded we may with propriety restrain, as we are beginning to do even in England, and we may safely prevent unions in which both parties are defective, for the evidence shows that as a rule such marriages, though often prolific, commonly produce no normal children at all. The union of such social vermin we should no more permit than we would allow parasites to breed on our own bodies. Further than that in restraint of marriage we ought not to go, at least not yet. Something too may be done by a reform of medical ethics. Medical students are taught that it is their duty to prolong life at whatever cost in suffering. This may have been right when diagnosis was uncertain and interference usually of small effect; but deliberately to interfere now for the preservation of an infant so gravely diseased that it can never be happy or come to any good is very like wanton cruelty. In private few men defend such interference. Most who have seen these cases lingering on agree that the system is deplorable, but ask where can any line be drawn. The biologist would reply that in all ages such decisions have been made by civilised communities with fair success both in regard to crime and in the closely analogous case of lunacy. The real reason why these things are done is because the world collectively cherishes occult views of the nature of life, because the facts are realised by few, and because between the legal mind—to which society has become accustomed to defer—and the seeing eye, there is such physiological antithesis that hardly can they be combined in the same body. So soon as scientific knowledge becomes common property, views more reasonable and, I may add, more humane, are likely to prevail.

To all these great biological problems that modern society must sooner or later face there are many aspects besides the obvious ones. Infant mortality we are asked to lament without the slightest thought

of what the world would be like if the majority of these infants were to survive. The decline in the birth-rate in countries already over-populated is often deplored, and we are told that a nation in which population is not rapidly increasing must be in a decline. The slightest acquaintance with biology, or even school-boy natural history, shows that this inference may be entirely wrong, and that before such a question can be decided in one way or the other, hosts of considerations must be taken into account. In normal stable conditions population is stationary. The laity never appreciates, what is so clear to a biologist, that the last century and a quarter, corresponding with the great rise in population, has been an altogether exceptional period. To our species this period has been what its early years in Australia were to the rabbit. The exploitation of energy-capital of the earth in coal, development of the new countries, and the consequent pouring of food into Europe, the application of antiseptics, these are the things that have enabled the human population to increase. I do not doubt that if population were more evenly spread over the earth it might increase very much more; but the essential fact is that under any stable conditions a limit must be reached. A pair of wrens will bring off a dozen young every year, but each year you will find the same number of pears in your garden. In England the limit beyond which under present conditions of distribution increase of population is a source of suffering rather than of happiness has been reached already. Younger communities living in territories largely vacant are very probably right in desiring and encouraging more population. Increase may, for some temporary reason, be essential to their prosperity. But those who live, as I do, among thousands of creatures in a state of semi-starvation will realise that too few is better than too many, and will acknowledge the wisdom of Ecclesiasticus who said 'Desire not a multitude of unprofitable children.'

But at least it is often urged that the decline in the birth-rate of the intelligent and successful sections of the population—I am speaking of the older communities—is to be regretted. Even this cannot be granted without qualification. As the biologist knows, differentiation is indispensable to progress. If population were homogeneous civilisation would stop. In every army the officers must be comparatively few. Consequently, if the upper strata of the community produce more children than will recruit their numbers some must fall into the lower strata and increase the pressure there. Statisticians tell us that an average of four children under present conditions is sufficient to keep the number constant, and as the expectation of life is steadily improving we may perhaps contemplate some diminution of that number without alarm.

In the study of history biological treatment is only beginning to be applied. For us the causes of the success and failure of races are physiological events, and the progress of man has depended upon a chain of these events, like those which have resulted in the 'improvement' of the domesticated animals and plants. It is obvious, for example, that had the cereals never been domesticated cities could scarcely have existed. But we may go further, and say that in temperate countries of the Old World (having neither rice nor maize) populations concentrated in large cities have been made possible by the appearance of a 'thrashable' wheat. The ears of the wild wheats break easily to pieces, and the grain remains in the thick husk. Such wheat can be used for food, but not readily. Ages before written history began, in some unknown place, plants, or more likely a plant, of wheat lost the dominant factor to which this brittleness is due, and the recessive, thrashable wheat resulted. Some man noticed this wonderful novelty, and it has been disseminated over the earth. The original variation may well have occurred once only, in a single germ-cell.

So must it have been with Man. Translated into terms of factors, how has that progress in control of nature which we call civilisation been achieved? By the sporadic appearance of variations, mostly, perhaps all, consisting in a loss of elements, which inhibit the free working of the mind. The members of civilised communities, when they think about such things at all, imagine the process a gradual one, and that they themselves are active agents in it. Few, however, contribute anything but their labour; and except in so far as they have freedom to adopt and imitate, their physiological composition is that of an earlier order of beings. Annul the work of a few hundreds—I might almost say scores—of men, and on what plane of civilisation should we be? We should not have advanced beyond the mediæval stage without printing, chemistry, steam, electricity, or surgery worthy the name. These things are the contributions of a few excessively rare minds. Galton reckoned those to whom the term 'illustrious' might be applied as one in a million, but in that number he is, of course, reckoning men famous in ways which add nothing to universal progress. To improve by subordinate invention, to discover details missed, even to apply knowledge never before applied, all these things need genius in some degree, and are far beyond the powers of the average man of our race; but the true pioneer, the man whose penetration creates a new world, as did that of Newton and of Pasteur, is inconceivably rare. But for a few thousands of such men, we should perhaps be in the Palæolithic era, knowing neither metals, writing, arithmetic, weaving, nor pottery.

In the history of Art the same is true, but with this remarkable difference, that not only are gifts of artistic creation very rare, but

even the faculty of artistic enjoyment, not to speak of higher powers of appreciation, is not attained without variation from the common type. I am speaking, of course, of the non-Semitic races of modern Europe, among whom the power whether of making or enjoying works of art is confined to an insignificant number of individuals. Appreciation can in some degree be simulated, but in our population there is no widespread physiological appetite for such things. When detached from the centres where they are made by others most of us pass our time in great contentment, making nothing that is beautiful, and quite unconscious of any deprivation. Musical taste is the most notable exception, for in certain races—for example, the Welsh and some of the Germans—it is almost universal. Otherwise artistic faculty is still sporadic in its occurrence. The cost of music well illustrates the application of genetic analysis to human faculty. No one disputes that musical ability is congenital. In its fuller manifestation it demands sense of rhythm, ear, and special nervous and muscular powers. Each of these is separable and doubtless genetically distinct. Each is the consequence of a special departure from the common type. Teaching and external influences are powerless to evoke these faculties, though their development may be assisted. The only conceivable way in which the people of England, for example, could become a musical nation would be by the gradual rise in the proportional numbers of a musical strain or strains until the present type became so rare as to be negligible. It by no means follows that in any other respect the resulting population would be distinguishable from the present one. Difficulties of this kind beset the efforts of anthropologists to trace racial origins. It must continually be remembered that most characters are independently transmitted and capable of such recombination. In the light of Mendelian knowledge the discussion whether a race is pure or mixed loses almost all significance. A race is pure if it breeds pure and not otherwise. Historically we may know that a race like our own was, as a matter of fact, of mixed origin. But a character may have been introduced by a single individual, though subsequently it becomes common to the race. This is merely a variant on the familiar paradox that in the course of time if registration is accurate we shall all have the same surname. In the case of music, for instance, the gift, originally perhaps from a Welsh source, might permeate the nation, and the question would then arise whether the nation, so changed, was the English nation or not.

Such a problem is raised in a striking form by the population of modern Greece, and especially of Athens. The racial characteristics of the Athenian of the fifth century B.C. are vividly described by Galton in 'Hereditary Genius.' The fact that in that period a population, numbering many thousands, should have existed, capable

of following the great plays at a first hearing, revelling in subtleties of speech, and thrilling with passionate delight in beautiful things, is physiologically a most singular phenomenon. On the basis of the number of illustrious men produced by that age Galton estimated the average intelligence as at least two of his degrees above our own, differing from us as much as we do from the negro. A few generations later the display was over. The origin of that constellation of human genius which then blazed out is as yet beyond all biological analysis, but I think we are not altogether without suspicion of the sequence of the biological events. If I visit a poultry-breeder who has a fine stock of thoroughbred game fowls breeding true, and ten years later—that is to say ten fowl-generations later—I go again and find scarcely a recognisable game-fowl on the place, I know exactly what has happened. One or two birds of some other or of no breed must have strayed in and their progeny been left undestroyed. Now in Athens we have many indications that up to the beginning of the fifth century so long as the phratries and gentes were maintained in their integrity there was rather close endogamy, a condition giving the best chance of producing a homogeneous population. There was no lack of material from which intelligence and artistic power might be derived. Sporadically these qualities existed throughout the ancient Greek world from the dawn of history, and, for example, the vase-painters, the makers of the Tanagra figurines, and the gem-cutters were presumably pursuing family crafts, much as are the actor-families[9] of England or the professorial families of Germany at the present day. How the intellectual strains should have acquired predominance we cannot tell, but in an in-breeding community homogeneity at least is not surprising. At the end of the sixth century came the 'reforms' of Cleisthenes (507 B.C.), which sanctioned foreign marriages and admitted to citizenship a number not only of resident aliens but also of manumitted slaves. As Aristotle says, Cleisthenes legislated with the deliberate purpose of breaking up the phratries and gentes, in order that the various sections of the population might be mixed up as much as possible, and the old tribal associations abolished. The 'reform' was probably a recognition and extension of a process already begun; but is it too much to suppose that we have here the effective beginning of a series of genetic changes which in a few generations so greatly altered the character of the people? Under Pericles the old law was restored (451 B.C.), but losses in the great wars led to further laxity in practice, and though at the end of the fifth century the strict rule was re-enacted that a citizen must be of citizen-birth on both sides, the population by that time may well have become largely mongrelised.

Let me not be construed as arguing that mixture of races is an

[9] For tables of families, see the Supplement to *Who's Who in the Theatre*.

evil: far from it. A population like our own, indeed, owes much of its strength to the extreme diversity of its components, for they contribute a corresponding abundance of aptitudes. Everything turns on the nature of the ingredients brought in, and I am concerned solely with the observation that these genetic disturbances lead ultimately to great and usually unforeseen changes in the nature of the population.

Some experiments of this kind are going on at the present time, in the United States, for example, on a very large scale. Our grandchildren may live to see the characteristics of the American population entirely altered by the vast invasion of Italian and other South European elements. We may expect that the Eastern States, and especially New England, whose people still exhibit the fine Puritan qualities with their appropriate limitations, absorbing little of the alien elements, will before long be in feelings and aptitudes very notably differentiated from the rest. In Japan, also, with the abolition of the feudal system and the rise of commercialism, a change in population has begun which may be worthy of the attention of naturalists in that country. Till the revolution the Samurai almost always married within their own class, with the result, as I am informed, that the caste had fairly recognisable features. The changes of 1868 and the consequent impoverishment of the Samurai have brought about a beginning of disintegration which may not improbably have perceptible effects.

How many genetic vicissitudes has our own peerage undergone! Into the hard-fighting stock of mediæval and Plantagenet times have successively been crossed the cunning shrewdness of Tudor statesmen and courtiers, the numerous contributions of Charles II. and his concubines, reinforcing peculiar and persistent attributes which popular imagination especially regards as the characteristic of peers, ultimately the heroes of finance and industrialism. Definitely intellectual elements have been sporadically added, with rare exceptions, however, from the ranks of lawyers and politicians. To this aristocracy art, learning, and science have contributed sparse ingredients, but these mostly chosen for celibacy or childlessness. A remarkable body of men, nevertheless; with an average 'horse-power,' as Samuel Butler would have said, far exceeding that of any random sample of the middle-class. If only man could be reproduced by budding what a simplification it would be! In vegetative reproduction heredity is usually complete. The Washington plum can be divided to produce as many identical individuals as are required. If, say, Washington, the statesman, or preferably King Solomon, could similarly have been propagated, all the nations of the earth could have been supplied with ideal rulers.

Historians commonly ascribe such changes as occurred in Athens, and will almost certainly come to pass in the United States, to

conditions of life and especially to political institutions. These agencies, however, do little unless they are such as to change the breed. External changes may indeed give an opportunity to special strains, which then acquire ascendency. The industrial developments which began at the end of the eighteenth century, for instance, gave a chance to strains till then submerged, and their success involved the decay of most of the old aristocratic families. But the demagogue who would argue from the rise of the one and the fall of the other that the original relative positions were not justifiable altogether mistakes the facts.

Conditions give opportunities but cause no variations. For example, in Athens, to which I just referred, the universality of cultivated discernment could never have come to pass but for the institution of slavery which provided the opportunity, but slavery was in no sense a cause of that development, for many other populations have lived on slaves and remained altogether inconspicuous.

The long-standing controversy as to the relative importance of nature and nurture, to use Galton's 'convenient jingle of words,' is drawing to an end, and of the overwhelmingly greater significance of nature there is no longer any possibility of doubt. It may be well briefly to recapitulate the arguments on which naturalists rely in coming to this decision both as regards races and individuals. First as regards human individuals, there is the common experience that children of the same parents reared under conditions sensibly identical may develop quite differently, exhibiting in character and aptitudes a segregation just as great as in their colours or hair-forms. Conversely all the more marked aptitudes have at various times appeared and not rarely reached perfection in circumstances the least favourable for their development. Next, appeal can be made to the universal experience of the breeder, whether of animals or plants, that strain is absolutely essential, that though bad conditions may easily enough spoil a good strain, yet that under the best conditions a bad strain will never give a fine result. It is faith, not evidence, which encourages educationists and economists to hope so greatly in the ameliorating effects of the conditions of life. Let us consider what they can do and what they cannot. By reference to some sentences in a charming though pathetic book, 'What Is, and What Might Be,' by Mr. Edmond Holmes, which will be well known in the Educational Section, I may make the point of view of us naturalists clear. I take Mr. Holmes's pronouncement partly because he is an enthusiastic believer in the efficacy of nurture as opposed to nature, and also because he illustrates his views by frequent appeals to biological analogies which help us to a common ground. Wheat badly cultivated will give a bad yield, though, as Mr. Holmes truly says, wheat of the same strain in similar

soil well cultivated may give a good harvest. But, having witnessed the success of a great natural teacher in helping unpromising peasant children to develop their natural powers, he gives us another botanical parallel. Assuming that the wild bullace is the origin of domesticated plums, he tells us that by cultivation the bullace can no doubt be improved so far as to become a better bullace, but by no means can the bullace be made to bear plums. All this is sound biology; but translating these facts into the human analogy, he declares that the work of the successful teacher shows that with man the facts are otherwise, and that the *average* rustic child, whose normal ideal is 'bullacehood,' can become the rare exception, developing to a stage corresponding with that of the plum. But the naturalist knows exactly where the parallel is at fault. For the wheat and the bullace are both breeding approximately true, whereas the human crop, like jute and various cottons, is in a state of polymorphic mixture. The population of many English villages may be compared with the crop which would result from sowing a bushel of kernels gathered mostly from the hedges, with an occasional few from an orchard. If anyone asks how it happens that there are any plum-kernels in the sample at all, he may find the answer perhaps in spontaneous variation, but more probably in the appearance of a long-hidden recessive. For the want of that genetic variation, consisting probably, as I have argued, in loss of inhibiting factors, by which the plum arose from the wild form, neither food, nor education, nor hygiene can in any way atone. Many wild plants are half-starved through competition, and transferred to garden soil they grow much bigger; so good conditions might certainly enable the bullace population to develop beyond the stunted physical and mental stature they commonly attain, but plums they can never be. Modern statesmanship aims rightly at helping those who have got sown as wildings to come into their proper class; but let not anyone suppose such a policy democratic in its ultimate effects, for no course of action can be more effective in strengthening the upper classes whilst weakening the lower.

In all practical schemes for social reform the congenital diversity, the essential polymorphism of all civilised communities must be recognised as a fundamental fact, and reformers should rather direct their efforts to facilitating and rectifying class-distinctions than to any futile attempt to abolish them. The teaching of biology is perfectly clear. We are what we are by virtue of our differentiation. The value of civilisation has in all ages been doubted. Since, however, the first variations were not strangled in their birth, we are launched on that course of variability of which civilisation is the consequence. We cannot go back to homogeneity again, and differentiated we are likely to continue. For a period measures designed to create a spurious

homogeneity may be applied. Such attempts will, I anticipate, be made when the present unstable social state reaches a climax of instability, which may not be long hence. Their effects can be but evanescent. The instability is due not to inequality, which is inherent and congenital, but rather to the fact that in periods of rapid change like the present, convection-currents are set up such that the elements of the strata get intermixed and the apparent stratification corresponds only roughly with the genetic. In a few generations under uniform conditions these elements settle in their true levels once more.

In such equilibrium is content most surely to be expected. To the naturalist the broad lines of solution of the problems of social discontent are evident. They lie neither in vain dreams of a mystical and disintegrating equality, nor in the promotion of that malignant individualism which in older civilisations has threatened mortification of the humbler organs, but rather in a physiological co-ordination of the constituent parts of the social organism. The rewards of commerce are grossly out of proportion to those attainable by intellect or industry. Even regarded as compensation for a dull life, they far exceed the value of the services rendered to the community. Such disparity is an incident of the abnormally rapid growth of population and is quite indefensible as a permanent social condition. Nevertheless capital, distinguished as a provision for offspring, is a eugenic institution; and unless human instinct undergoes some profound and improbable variation, abolition of capital means the abolition of effort; but as in the body the power of independent growth of the parts is limited and subordinated to the whole, similarly in the community we may limit the powers of capital, preserving so much inequality of privilege as corresponds with physiological fact.

At every turn the student of political science is confronted with problems that demand biological knowledge for their solution. Most obviously is this true in regard to education, the criminal law, and all those numerous branches of policy and administration which are directly concerned with the physiological capacities of mankind. Assumptions as to what can be done and what cannot be done to modify individuals and races have continually to be made, and the basis of fact on which such decisions are founded can be drawn only from biological study.

A knowledge of the facts of nature is not yet deemed an essential part of the mental equipment of politicians; but as the priest, who began in other ages as medicine-man, has been obliged to abandon the medical parts of his practice, so will the future behold the schoolmaster, the magistrate, the lawyer, and ultimately the statesman, compelled to share with the naturalist those functions which are concerned with the physiology of race.

REPORTS

ON THE

STATE OF SCIENCE.

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Seismological Investigations.—Nineteenth Report of the Committee, consisting of Professor H. H. Turner (*Chairman*), Professor J. Perry (*Secretary*), Mr. C. Vernon Boys, Mr. Horace Darwin, Mr. F. W. Dyson, Dr. R. T. Glazebrook, Mr. M. H. Gray, Professor J. W. Judd, Professor C. G. Knott, Sir J. Larmor, Professor R. Meldola, Mr. W. E. Plummer, Dr. R. A. Sampson, Professor A. Schuster, Mr. J. J. Shaw, *and* Dr. G. W. Walker. (*Drawn up by the Chairman.*)

[Plate I.]

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I.—*General Notes.*

The Committee asks to be reappointed with a grant of 60*l.*

The death of John Milne, in July 1913, creates a situation of some difficulty and anxiety. He organised a world-wide seismological service with very little financial help from others. In many of the outlying stations the instrumental equipment was provided either by himself or by one of his friends, and the care of it has been generously undertaken by a volunteer who is often busily engaged in other work. The collation of results was in the early years undertaken by Milne himself, with the able help of Shinobu Hirota. Of late years a subsidy of 200*l.* a year from the Government Grant Fund allowed of paid assistants; and Shinobu Hirota thus obtained a well-deserved official position; but for many years the only salary he received was paid from Milne's own pocket. It is by no means certain that the volunteer services at the stations, and the subsidy from the Government Grant Fund which makes it possible to keep running the central station at Shide, can be long continued; and it seems in any case very improbable that they can be rendered permanent. But a much more serious difficulty is the want of a salary for a Director or Superintendent of the whole British network of stations, who can give undivided attention to the valuable results which they have accumulated and to which they are daily adding. The salary of

a competent Director, with the requisite mathematical knowledge, cannot be put lower than 500*l*. or 600*l*. a year, and there is at present no prospect of obtaining even this endowment. The superintendence has, of course, been hitherto provided voluntarily by Milne himself; and a certain amount of volunteer attention is available for the present. But seismology is developing so rapidly that the whole-hearted attention of at least one English mathematician should be devoted to it; and if an endowment for a British Director could be obtained this would surely be the most direct method of doing justice to a new and fascinating science which was nurtured by an Englishman. The negative result of previous appeals to the Government does not encourage the hope of their taking any action, and the chief hope thus lies in the direction of private benefaction. Is it too much to hope that some generous benefactor will provide a firm footing for seismology?

The present state of affairs is as follows:—The Shide Observatory is rented from Mrs. Milne at 20*l*. a year. The work of the Shide station and the collation of results from other stations is being done by Mr. J. H. Burgess, who assisted Professor Milne in the later years of his life, especially after the return of Shinobu Hirota to Japan. At the time of Professor Milne's death the work of collation was in arrear; and in order to bring it up to date assistance is being temporarily rendered by Mr. S. W. Pring (who had already considerable knowledge of the work) and his daughter. The general superintendence is undertaken by the Chairman of this Committee, partly by correspondence and partly by personal visits to Shide (on September 20-21, January 17-20, March 29-April 2, and May 9-11).

Registers. Card Catalogue System. Monthly Bulletins.—The form of the Circulars has been changed. Up to the present the information supplied by each individual station has been printed separately, thus leaving the formal collation of results to others. But since a good deal of collation was actually done at Shide in order to eliminate accidental tremors from the records, it seemed desirable to render this work generally available at the cost of a slight extension. The collation was formerly done in a large book with ruled columns, one double page being devoted to each month. In place of this a card catalogue system has been adopted. The information supplied by the stations is copied on to cards, a separate card for each day. A cabinet of twelve drawers (one for each calendar month) has been made, each drawer divided into 32 partitions (4×8) corresponding to the days of the month (with 1—4 over), and the cards are slipped into the proper partition as they are copied off. When all the records have been received for the month (and the stations have been asked kindly to send their records *each month*) it is easily seen by comparison of the different cards in any partition which are the important quakes and which are microseisms or accidental tremors. For the first few months of 1913 details were printed for all disturbances recorded at more than four stations; but experience quickly showed that much of this information was of

comparatively little value, the records for small quakes being liable to errors of various kinds; and from April 1913 onwards a chart has been printed showing merely that such and such a quake has been observed at a particular station without further details, except in the case of a really large earthquake. It is, of course, difficult to draw a satisfactory line between large earthquakes and small, but a practical procedure was based on the following figures given in the April Bulletin:—

Month	Number of Stations recording an Earthquake:					
	5 to 10	11 to 20	21 to 30	31 to 40	41 to 50	Over 50
January . . .	3	5	3	2	4	2
February . . .	5	5	5	1	0	1
March	6	9	7	3	2	3
April	9	13	6	10	4	3
Total . .	23	32	21	16	10	9

According to this table, if attention is confined to those earthquakes recorded at thirty-one stations at least, we should get a hundred of them in a year; and it was thought sufficient to give full details for these. It should be remarked that the stations are no longer Milne stations only—the list has been extended to include all those stations which send their records to Shide; and it is hoped that this comprehensive collation of results will be found useful. Undoubtedly a comparison with tabular theoretical results would increase its usefulness, and it is hoped to undertake such a comparison from January 1914; but to attempt this for 1913 would have seriously delayed publication (already considerably in arrear), and indeed was scarcely possible until a tentative discussion such as is given later in the present Report had been carried out.

Notation.—One other change will be made in January 1914. The symbols P_1, P_2, P_3, &c., were introduced by Milne, and have been used by him throughout his work, although he assented to the change to P, S, L, &c., as determined at the Manchester Meeting, 1911, of the International Seismological Association. It seemed only a proper mark of respect to complete the year of Milne's death (1913) in his notation; but the change to the adopted system will be made from the beginning of 1914.

Visitors.—The station at Shide continues to attract a number of visitors, many of them with only a limited knowledge of seismology; their visits naturally make inroads on the time of the assistant-in-charge, but it seems undesirable to discourage them at the present juncture. The visits of seismologists have naturally been affected by Milne's death; and in the consequent disorganisation the visitors' book was for a time not regularly posted; but we have had the pleasure of seeing at Shide Mr. J. J. Shaw of West Bromwich, Mr. E. F. Norris of Guildford, Mr. J. Round and Mr. S. B. Round of

Birmingham, Mr. L. F. Richardson of Eskdalemuir, and Mr. J. E. Crombie of Aberdeen.

II.—*Seismic Activity in* 1911.

The visit of the British Association to Australia makes it necessary to have the greater part of this Report in proof at an earlier date than usual. The list of origins for 1911, in continuation of those given in previous Reports, is not completed at this date; but it is hoped to add it at the end of the Report before it is finally printed off for distribution.

III.—*Distribution of Earthquake Centres.*

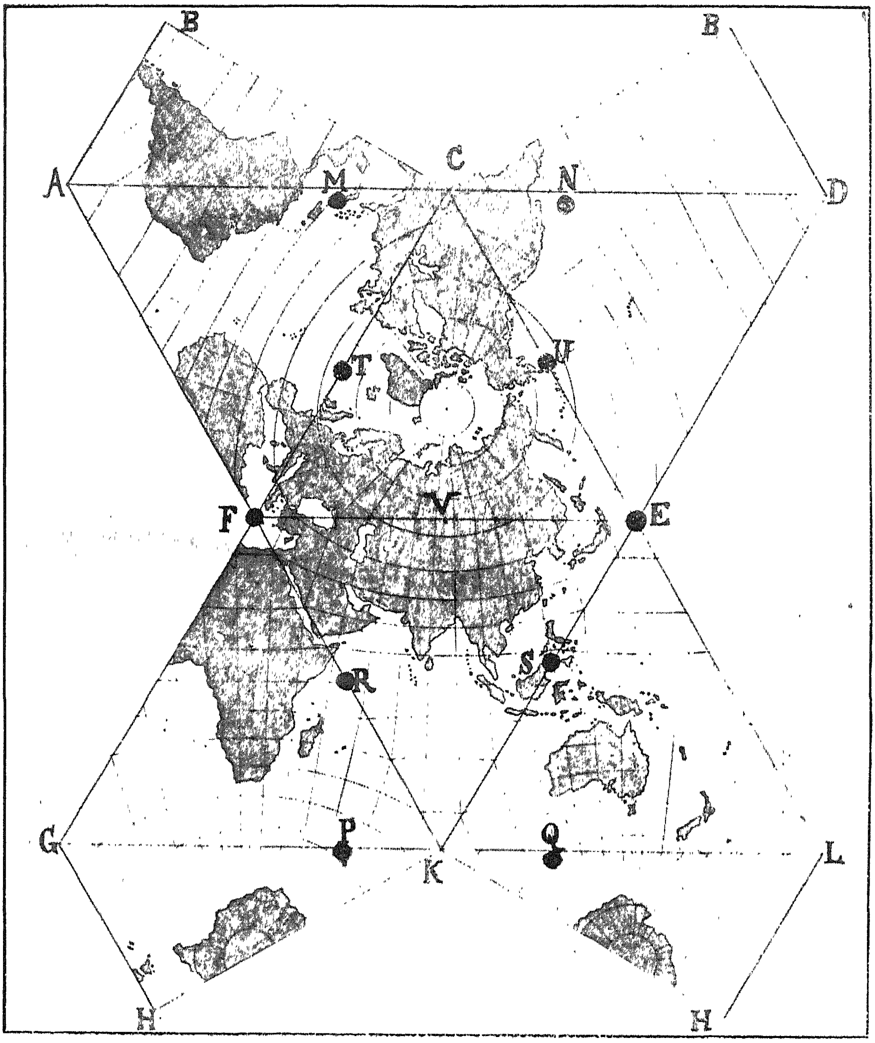
Study of the information collected by Milne in previous Reports has suggested a new form of the map which he has usually printed showing the distribution of large earthquakes. On some of these maps he has shown Libbey's Circle, and on others a cycle of his own running through the chief earthquake centres.

On scrutiny of the distribution of centres not thus accounted for, the existence of a curve of secondary disturbance was suggested, with the suggestive feature of enclosing most of the land on the earth's surface—skirting especially the Western coast of North America and the Eastern coast of Asia. Adjustments by trial and error of these two curves showed that it was not difficult to make them great circles cutting at right angles; but not easy to make them account for all the striking facts. More or less by accident, the third great circle cutting both at right angles was drawn, and immediately several striking *geographical* features fell into line. Further work on this system of three great circles suggested after many trials a system symmetrical with respect to the earth's axis, the points of intersection being at about 55° (accurately $\tan^{-1} \sqrt{2}$) from the poles; and there was little trouble in fixing the approximate longitudes at 25° ± 60° n East.

A system of three great circles cutting at right angles divides the surface of the sphere into eight equilateral right-angled triangles. If we project each of these on a tangent plane at its centre, we get an octahedron surrounding the sphere, and we can unwrap it into a plane in various ways. The particular plan of the accompanying map is adopted in order to bring out the striking symmetry, both seismological and geographical, of the earth as thus represented, a symmetry only slightly disguised by the one-sidedness of the water covering. [We can imagine the distribution made quite symmetrical, and then the upper right-hand corner dipped slightly more under the water; but we will neglect this point for a moment.]

Six of the triangles are easily recognised, the other two have been divided by their median lines in order to show the symmetry while keeping the figure compact; but ABC and CBD could be detached from AC and CD, and joined along CB placed in a vertical position, thus keeping the symmetry at the expense of a little detachment.

Let us consider the triangle EFK, which is chiefly Asia. India lies nearly on the median line, pointing to the apex of the triangle; and just



Illustrating the Report on Seismological Investigations.

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above India Tibet, the highest land in the world, occupies nearly the centre of the triangle. The side KE runs through a well-known series of earthquake centres skirting the coast, of which perhaps the most important are at E (Japan) and S (Borneo), one at the extremity and the other near the middle point. The continuation of KE is EC, since the angles FEK and FEC, though they are only 60° on the plane projections, are 90° on the sphere; and since there is a notable centre U (Alaska) near the middle of EC, we may perhaps consider S and U as corresponding points of strain.

The side KF is not so conspicuous a line of earthquakes at present, though the point F (Crete) is a familiar region, and corresponding to S we may take R, the middle point of FK, as representing earthquakes in the Indian Ocean. But apart from modern records, the geographical features of this line RF, viz., the Red Sea, the Grecian Archipelago, and the Adriatic, are strongly suggestive of crumpling into folds at some time in the past. Continuing the line along FC, there is an active centre near the middle point T which is not far from Iceland; so that S, E, V have corresponding points in R, F, T; the former are at present the stronger, but this may not have been always so.

The apex C is not an earthquake centre, but near it, and symmetrically disposed on the sides CD, CA, are the Californian and West Indian regions. The symmetry of the whole arrangement round the point V (close to Tomsk) will be complete if we may put two Antarctic centres at the points P and Q which are in latitude $-53°$ and longitudes 55° and 115° East. Milne assigned two Antarctic regions near these as a result of observations made during the voyage of the 'Discovery' (March 14, 1902, to November 28, 1903), but it is doubtful whether the material is sufficient to locate them exactly.

As regards the remainder of the map, the symmetrical disposition of South Africa and Australia is noteworthy; but as we go northwards from them the symmetry disappears, the upper half of the African triangle being land, that of the Australian water (though much of it not very deep). Superposed on the arrangement symmetrical about the line CK there is at least one unsymmetrical character which may be roughly described as a division into land and water hemispheres, and as such has been often noted. In the present diagram the salient points of this contrast are:—

(*a*) Land in the triangle FGK, water in the triangle CDE.

(*b*) Water in the middle of land in the triangle ACF, land in the middle of water in EKL.

(*c*) The absence of land corresponding to South America, on the line CD. If a bathy-orographical map be consulted it will, however, be found that there is a shallow in this part of the ocean, not very different from South America in shape. It is conceivable that a mere shift of the earth's centre of gravity might uncover this 'image' of South America.

In a future Report it is hoped to show the actual distribution of observed earthquakes on this map; but this will take some little time.

IV.—*Discussion of Results from Different Seismographs.*

The card catalogue system introduced at Shide for records from January 1913 onwards facilitates the comparison of results from different instruments. The following discussion is only preliminary, and the unit of time adopted (0·1 m. or 6 sec.) is not small enough to do justice to the best instruments. But it is as small as can reasonably be adopted for the Milne instruments, and the main object of the discussion is to bring out the comparative attainments of the Milne seismographs as compared with modern and much more sensitive apparatus.

From the beginning of 1912, the weekly Bulletins issued from Pulkovo give epicentres for the large earthquakes, determined by Galitzin's method for a single station. Adopting these as correct and using the table printed by G. W. Walker on p. 54 of his monograph on 'Modern Seismology,' or by Galitzin in his 'Vorlesungen über Seismometrie,' p. 137, we can deduce from the times recorded at Pulkovo for either P or S, the time of the earthquake itself. Reapplying the table we can deduce the theoretical times of arrival of P and S at other stations, for comparison with their records. For this purpose the distances of the stations from the epicentre were read to whole degrees from a globe, which again is a method unsuitable to refined investigation, but sufficiently accurate for the present preliminary examination.

As an example, the times recorded for the earthquake of 1913, January 11, were as follows:—

	P			S		
	h.	m.	s.	h.	m.	s.
	13	29	45	13	40	9
Subtract		12	36		22	54
Time at epicentre	13	17	9	13	17	15

The distance of Florence from the adopted epicentre (6° N., 117° E.) was read off as 98°, and the calculated and observed times were:

For P					For S				
C		O		O—C	C		O		O—C
h.	m.	h.	m.	m.	h.	m.	h.	m.	m.
13	31·1	13	30·2	−0·9	13	42·7	13	35	−7·7

These differences O—C were collected and discussed for the following five earthquakes:—

Date	Adopted Epicentre	Δ for Pulkovo	Adopted Time	
	° °	°	h.	m.
1913, January 11	6·0 N., 117·0 E.	83	13	17·2
1913, March 23	26·3 N., 143·3 E.	78	20	47·2
1913, April 30	50·2 N., 176·3 E.	67	13	34·4
1913, May 18	26·3 N., 143·7 E.	79	2	9·7
1913, June 22	50·1 N., 178·1 E.	66	13	50·3

TABLE I.

134 *Errors of P for Seismographs other than Milne's.*

	Distance from Epicentre 0° – 40°	– 80°	– 90°	– 100°	– 130°	Summary (Corrected)
Large Errors .	—	—	m. +10·3 +10·1 + 9·2	m. +10·6 +10·4 —	— — —	— — —
m. m. +5·5 to 5·1	—	—	—	—	1	—
5·0 to 4·6	—	—	—	2	1	—
4·5 to 4·1	—	—	—	7	—	—
4·0 to 3·6	—	—	2	14	—	—
3·5 to 3·1	—	—	—	4	2	—
3·0 to 2·6	—	—	—	1	—	—
2·5 to 2·1	—	—	—	1	—	—
2·0 to 1·6	1	—	—	2	—	—
+1·5 to 1·1	1	—	—	—	1	—
+1·0	—	—	—	—		—
0·9	—	1	—	—		2
0·8	1	1	—	—		2
0·7	1	1	1	—		3
0·6	—	1	—	1		3
0·5	1	—	—	—		1
0·4	2	2	1	1		4
0·3	—	3	—	1		6
0·2	1	2	—	—		8
+0·1	2	6	3	1		11
0·0	—	4	2	1	None	14
−0·1	—	4	4	3		9
0·2	—	3	5	2		5
0·3	2	2	2	4		4
0·4	1	1	—	—		4
0·5	—	1	1	—		3
0·6	1	1	—	2		3
0·7	—	—	—	—		1
0·8	—	—	—	1		0
0·9	—	1	—	2		2
−1·0	—	—	—	—		1
−1·1	—	—	1	—		0
−1·2	—	1	—	1		1
Large Errors .	—	− 3·3 − 4·2 −14·2 −24·8	−2·3 −3·3 −5·0 —	— −3·4 — —	— — — —	— — — —

In Table I. the differences are grouped under distances from epicentre, all instruments *other than Milne* being grouped together.

Errors greater than 6 *m.*—The five large positive residuals are as follows:—

Observatory	Instrument	Date	Errors P	Errors S	Dist. from Epicentre
			m.	m.	°
Triest	W	1913, Jan. 11	+10·6	+7·4	95
Triest	W	1913, May 18	+10·4	—	96
Triest	W	1913, June 22	+10·3	—	83
Czernowitz	Ma.	1913, May 23	+10·1	+9·5	89
Pompeii	O.A.	1913, June 22	+ 9·2	—	88

The difference between the times of arrival of P and S being near 10 m. it is possible that some of these are mistakes of P for S. But in the case of Czernowitz, a mistake of 10 m. in both P and S seems probable. It is safer to omit these cases as anomalies than to attempt to correct them.

Errors. <6 *m. and* >1 *m.*—With the exception of a couple near the epicentre these do not develop until near 90°. Between 90° and 100°, however, they outnumber the normal errors given in the body of the table. They are doubtless due to the fact that a reflected wave has been mistaken for the direct wave. The fact that the first reflected effect PR is often more pronounced than P in the case of distant earthquakes is duly noted in Walker's monograph (p. 41); it may not, however, be realised that it is so often mistaken for P in the published records of sensitive instruments. Beyond 100° from the epicentre *no* times for P were correctly given at all for the five earthquakes here examined. It is not intended to ignore the fact that these differences will change with distance from epicentre, but for the present rough review we will neglect this change. The median is 3·75 m. or 3 m. 45 s. The mean of the differences from this is ± 0·53 m. But it does not seem clear that some of the differences which *may* be faulty P readings should be included. If these are excluded the median is 3·8 m.; the mean is 3·87 m.; and the mean of the differences from the mean is ± 0·35 m.

Normal Errors.—Coming now to the main part of Table I., if we take the errors as they stand (assuming the time-table for P correct throughout) the mean of the 87 differences is − 0·07 m. or − 4 s. But there is a systematic run about the differences as may be seen from the following means for the separate columns:—

0° — 40°	— 80°	— 90°	— 100°
m.	m.	m.	m.
+0·13	+0·01	−0·11	−0·27

The process adopted in the previous work does not justify any great refinement of correction; but we may fairly correct the different columns by the quantities

0° — 40°	— 80°	— 90°	— 100°
m.	m.	m.	m.
−0·1	0·0	+0·1	+0·3

and then the errors are distributed as in the last column. The mean is now +0·014 m. or +0·8 s. and the mean of the errors is ± 0·31 m., very close to the mean of the errors 0·35 m. obtained above for the reflected wave. A considerable part of this mean error may be due to the errors of reading distances from the epicentre, and to the error of assumed position of the epicentre itself.

Large Negative Readings.—The eight negative readings are probably due to accidental air tremors just preceding the quake; these call for no special remark here except that they seem to be pretty clearly separated off from the normal readings; even making a generous allowance for accidental error in the latter. It will be seen that the numerically smallest (–2·3 m.) is a full minute away from the outside error (–1·2 m.) included among possible normal readings. The details may be given here in case the observatories care to examine the records:—

Observatory	Instrument	Date	Errors P	Errors S	Dist. from Epicentre
			m.	m.	°
Lemberg	B.O.	Jan. 11, 1913	–3·3	—	88
Lemberg	B.O.	Mar. 23, 1913	–5·0	—	87
Lemberg	B.O.	April 30, 1913	–14·2	—	79
Lemberg	B.O.	June 22, 1913	–4·2	–3·9	78
Aachen	W.	April 30, 1913	–24·8	—	80
Paris	—	Mar. 23, 1913	–3·4	–0·7	98
Ksara	—	Mar. 23, 1913	–2·3	—	90
Batavia	W.	Mar. 23, 1913	–3·3	—	47

Coming now to S, two large positive errors have already been mentioned as associated with large positive errors in P, viz., +9·5 m. at Czernowitz on 1913, March 23, and +7·4 m. at Triest on 1913, January 11, as also one considerable negative error of –3·9 m. at Lemberg on June 22, 1913. These are omitted from further notice. Two large negative errors are

Observatory	Machine	Date	P	S	Δ
Tiflis	G	1913, Jan. 11	+0·2	–8·1	73°
Florence . . .	A	1913, Jan. 11	–0·9	–7·7	98°

The former is due to some unknown mistake; the latter is probably a mistake of S for PR_1. These are also omitted from further notice. Two positive errors of smaller amount as follows:—

Observatory	Date	P	S	Δ
Riverview	1913, June 22	–0·3	+4·5	94°
Heidelberg	1913, June 22	+0·1	+4·7	80°

are omitted as quite anomalous. The remaining errors are grouped in Table II.

TABLE II.

Errors of S for Seismographs other than Milne's.
(Unit 0·1 m. or 6 s.)

Errors	Distance from Epicentre 0°	40°	80°	130°
+2·1 to +2·5	—	—	1	—
+1·6 to +2·0	1	—	3	—
+1·1 to +1·5	2	3	1	—
+0·6 to +1·0	1	3	1	—
+0·1 to +0·5	1	4	3	—
−0·4 to 0·0	2	10	9	—
−0·9 to −0·5	1	4	12	—
−1·4 to −1·0	—	3	12	—
−1·9 to −1·5	—	2	7	—
−2·4 to −2·0	—	1		—
−2·9 to −2·5	—	—		—
Mean . .	+0·5	−0·2	−0·5	—

It would hereby appear that while the tables for P are fairly accurate, those for S are sensibly in error. The amount of error cannot be assigned more than very roughly by the present method, because the error for Pulkovo comes differently into the various earthquakes. But it would appear that the times of arrival of S at 20° distance and at 100° distance from the epicentre are relatively erroneous by something like a whole minute. The error is apparently not complicated in the case of S by any reflection phenomenon; the residuals for P are definitely grouped about two separate maxima, but for S this is not so. The first group (0°–40°) is too small to show a decided maximum; but the position of the maximum is clearly marked in the other two by the numbers given in the table. As a rough expedient the following corrections have been applied:—

	Distance from Epicentre 15°	25°	35°	45°	55°	65°	75°	85°	95°	105°
Correction .	−0·3	−0·2	−0·1	0·0	+0·1	+0·2	+0·3	+0·4	+0·5	+0·6

the correction for 15° being applied to distances between 10° and 20°, and so on. The corrected errors are then distributed as follows:—

	Distance from Epicentre 0° — 40°	40° — 80°	80° — 130°	All
+2·8 to +3·2	—	—	1	1
+2·3 to +2·7	—	—	3	3
+1·8 to +2·2	—	—	—	0
+1·3 to +1·7	1	1	2	4
+0·8 to +1·2	2	6	—	8
+0·3 to +0·7	2	4	6	12
−0·2 to +0·2	—	11	13	24
−0·7 to −0·3	2	2	12	16
−1·2 to −0·8	1	4	10	15
−1·7 to −1·3	—	2	1	3
−2·2 to −1·8	—	1	—	1
Totals . . .	8	31	48	87

The mean of the errors is ± 0·73 m., and though there is a slight tendency to increase from the second group to the third, the material is fairly homogeneous. Now, comparing this with the mean for P, viz. ± 0·31 m., it is clear that we are dealing with a much less definitely marked phenomenon, as is indeed well known. Part of each of these mean errors is due to errors of reading, &c.; and this part should be approximately the same in both. If we were to calculate and remove it, the ratio between the two, already greater than 2 to 1, would be sensibly increased.

In determining Δ from P and S, the superior accuracy of P is therefore rendered more or less useless by the uncertainty of S. Galitzin's azimuthal method of determining the epicentre has thus obvious advantages; if the epicentre is well determined from the azimuths at several stations, and if the time of the catastrophe is determined from the P's at these stations, we should appear to have the material in the best shape for improving the tables of P and S, especially the latter.

But this is a digression from the present investigation, which is primarily concerned with the performance of the Milne instruments.

Putting aside for the present any question of correcting the tables for S, and therefore the position of the epicentre (as determined from Pulkovo), and consequent correction of the calculated times, it is clear that we can compare the performance of the Milne pendulums with other instruments on a common basis (though not the ultimate basis) by collecting their records for the same earthquakes in the same way. This is done in the following Table III., which corresponds to Table I.

It will be seen—

(*a*) That there are 5 large positive errors and 8 large negative errors, for which no special explanation can be given. In Table I. there are 8 negative errors, no positive.

(*b*) That in $6+5+10+5=26$ cases, S has presumably been read in place of P. With other instruments there were only 5 such cases.

(*c*) That in at least 17 cases a reading has been made which can be attributed to a reflected wave. There are, moreover, 9 readings intermediate between these and the normal readings, which are extreme cases of one or the other. The line of demarcation is not so sharp as before. Similarly there are 5 doubtful negative readings.

(*d*) In the middle part of the table have been collected within the same limits as before what may be fairly regarded as normal readings.

They number 25 in all. They do not of themselves suggest any corrections to the table for P, but we might use the same corrections as before. It is simpler, however, to restrict attention to the second and largest group, the mean of the errors for which is ± 0·4 m. If, however, we include in this the 'doubtful' +1·8 m., +1·4 m., +1·2 m., and −1·0 m., −1·2 m., the mean of the errors rises to ± 0·6 m. For other instruments this mean was ± 0·31 m.

The most significant fact is perhaps that of the whole 95 readings only 25 at a severe scrutiny, and at most (*i.e.*, including

TABLE III.

95 *Errors of P for Milne Seismographs in* 1913.

Error	Distance from Epicentre 0° — 40°	— 80°	— 90°	— 100°	— 130°	
Large Positive	—	+18·7	+39·4	+40·7	—	—
	—	+15·3	—	+25·0	—	—
Transferred to S	—	(6)	(5)	(10)	(5)	—
PR_1	—	+4·3	—	(9)	(6)	—
	—	+3·3	—	—	—	—
Doubtful	—	+2·9	—	+2·8	+2·0	—
	—	+2·7	—	+2·0	—	—
	—	+1·8	—	+1·4	—	—
	—	+1·4	—	—	—	—
	—	+1·2	—	—	—	—
m.						
+0·9	—	1	—	—	1	—
+0·8	—	1	—	—	—	—
+0·7	—	—	1	—	—	—
+0·6	—	—	1	—	1	—
+0·5	1	1	—	—	—	—
+0·4	—	1	—	—	—	—
+0·3	1	3	—	—	—	—
+0·2	—	2	—	—	—	—
+0·1	—	2	—	—	—	—
0·0	—	1	—	—	—	—
−0·1	—	—	—	—	—	—
−0·2	2	1	1	—	—	—
−0·3	—	1	—	—	—	—
−0·4	—	—	—	—	—	—
−0·5	—	—	—	—	—	—
−0·6	—	—	—	—	—	—
−0·7	—	1	—	—	—	—
−0·8	—	—	—	—	—	—
−0·9	—	1	—	1	—	—
Doubtful	−1·2	−1·0	—	−1·9	−1·0	—
	—	−1·2	—	—	—	—
Large Negative	—	− 3·4	—	−5·4	−12·4	—
	—	− 5·8	—	—	−17·5	—
	—	−10·1	—	—	−25·4	—
	—	−35·3	—	—	—	—

all those marked doubtful) only 39, can be regarded as true readings of P; say 40 per cent. at most. With the other machines there are 87 out of 134, or 65 per cent.

Coming now to S, and correcting the results (which include those transferred from P) as for other instruments, we find 12 large errors; the others are distributed as below:—

Table IV.

38 *Errors for S in Milne Seismographs in* 1913.

	Distance from Epicentre 0° — 40°	— 80°	— 130°	All
m. m.				
+3·3 to +3·7	—	1	1	2
+2·8 to +3·2	—	—	—	—
+2·3 to +2·7	—	—	3	3
+1·8 to +2·2	—	1	1	2
+1·3 to +1·7	—	—	1	1
+0·8 to +1·2	—	1	2	3
+0·3 to +0·7	2	2	2	6
−0·2 to +0·2	—	3	3	6
−0·7 to −0·3	—	2	5	7
−1·2 to −0·8	—	—	2	2
−1·7 to −1·3	—	2	2	4
−2·2 to −1·8	—	—	1	1
−2·7 to −2·3	—	1	—	1

The mean of the errors is $\pm 1·1$ m.; for other instruments it was $\pm 0·73$ m. The ratio of these is about the same as in the case of P. But it will be seen that there are acceptable readings of S in 38 cases, whereas for the same earthquakes there are only 39 of P at most. It is usually considered that the Milne instruments show P but not S. The evidence here tabulated points to the conclusion that S is shown at least as well as P. It is true that the five earthquakes considered are large ones; but it might reasonably be argued that P should therefore have the better chance of asserting itself. It seems probable that in some cases P could be recovered from the records when it was realised that the reading formerly given was that of S. The important point is that without any great difficulty it can be settled when we have an S reading, for the cases of doubt are few. We may now give the 12 large errors excluded as mistakes; they are $+35·2$ m., $+11·9$ m., $+10·3$ m., $+9·1$ m., $+8·7$ m., $+8·6$ m., the smallest of which exceeds the maximum error ($+3·5$ m.) accepted as S by over 5 m.; and on the negative side we have $-4·4$ m., $-4·4$ m., $-5·1$ m., $-8·0$ m., $+11·8$ m., and $-14·2$ m. Here the separation is not so marked; but there is a full 2 m. interval. Some or all of these negative errors may be readings of PR_1, but the two largest, which both occur on January 11 (Toronto $-11·8$ m. and Stonyhurst $-14·2$ m.), are supported by several other readings and probably refer to a preliminary shock. As the performance of the Milne pendulums is the main point under

investigation, not only were the above five earthquakes used, but also five others in 1911 as follows:—

—	Date	Adopted Epicentre	Adopted Time		
		° °	h.	m.	s.
I. . . .	1911, July 4	39·0 N., 71·4 E.	13	33	33
II. . . .	1911, July 12	27·0 N., 116·0 E.	4	9	7
III. . . .	1911, Aug. 16	19·0 S., 140·0 E.	22	38	51
IV. . . .	1911, Oct. 14	33·5 N., 82·5 E.	23	24	1
V. . . .	1911, Dec. 16	12·0 N., 101·8 W.	19	13	51

For these earthquakes Pulkovo epicentre determinations were not available, but the results from Galitzin instruments at Eskdalemuir are published in the 'Geophysical Journal,' and have been adopted for use. The computations were kindly made by Mr. A. E. Young, formerly Deputy Surveyor-General of the Malay Survey, who is at present working at the Oxford University Observatory; and in this instance greater care was taken, Mr. Young calculating the distances trigonometrically (instead of reading them from a globe) and using the times and tables to seconds of time in the computations, though in giving the results the unit 0·1m. has been considered sufficient.

V.—*Comparison of Films for* 1911.

The chief object in using this additional material was as follows. It was thought that some of the errors of the Milne instruments might be due to faulty readings of the records, susceptible of correction. To test the general accuracy of such readings the different stations were invited to send their films for the year 1911 to Shide, and many of them have responded. Some had bound up their films in such a way that transmission was undesirable; but films for 1911 have been received at Shide from Cape Town, Cork, Toronto, San Fernando, Sydney, Helwan (Egypt), Victoria, Ascension, Perth, Seychelles, Eskdale, Guildford, and Colombo, and have been systematically examined at Shide by Mr. Burgess and Mr. Pring, who have had much experience in reading the Shide films. It was thought advisable to make this examination quite independently, before knowing whether the revised readings would suit the calculated facts better; and indeed the calculations were made at Oxford, so that the Shide readings were made in ignorance of the tabular result either before or after. On comparing the old and new readings with expectation, it does not appear that the new afford any systematic improvement on the old. The actual figures for the above five earthquakes are as follows (the quantities given being differences from expectation, calculated as already indicated). They apply entirely to the phase P, the phase S being seldom read from the Milne records.

Table V.

Comparison of Original and Revised Readings of Various Films for the Phase P.

Ascension.

Quake.	Orig.	Rev.
II.	−5·5	Not read
III.	+5·1	+5·1

Cape Town

I.	−0·9	+0·2
II.	+2·3	+2·9
III.	+6·3	+5·8
V.	+5·5	+5·1

Helwan.

Readings for Jan. and Feb. confirmed former results so consistently that the scrutiny was discontinued as superfluous.

Perth.

III.	+3·5	+3·5
V.	+2·4	+2·5

San Fernando.

I.	−0·2	−3·0
III.	+5·9	+6·6
IV.	+6·5	+21·7
V.	−0·3	−0·7

Seychelles.

Quake.	Orig.	Rev.
I.	+6·0	Not read
II.	+0·0	−1·0
III.	+1·5	+1·5
V.	(37·0)	(34·0)

For V. epicentre is so distant that tables fail.

Sydney.

I.	+2·8	−14·4
II.	−4·5	−41·9
III.	+1·7	−13·2
IV.	+9·6	+ 9·2

For II. an earlier quake is confirmed by Alipore. For III. see Toronto.

Toronto.

I.	+10·1	−14·4
II.	+ 4·9	+ 4·1
III.	+ 9·7	−14·3
V.	− 0·3	− 1·1

For III. see Sydney.

Victoria.

V.	− 0·1	− 0·1

Films not sent for other earthquakes.

After consideration of the above figures, it was decided to apply no corrections at all, but to accept the original readings as they stand, and in Table VI. these are compared with calculated values. The table corresponds to Table III. except that Δ was now used in km., and the grouping is therefore a little different.

There is room for some difference of opinion as to the 17 records marked doubtful; but the $12+13+15+3+4=47$ readings in the body of the table are probably normal. We thus get at least 47 but not more than 64 normal readings out of 108. These figures are better than the 1913 figures and encourage the hope that on the whole 50 per cent. of the recorded readings for P may be normal; but the percentage cannot be higher than this.

One feature of the records seems to demand further investigation. There is a suggestion that the readings are divisible into two groups separated by about a whole minute; and this applies also to the results for 1913, though they are scarcely numerous enough to declare it independently. It will be seen that the records $-0·4$ m. and $-0·5$ m. are not represented in either table, thus creating an appearance of separation. But this may be purely accidental.

Coming now to S, Table VII. has been formed in the same manner as before, adopting the same corrections to the tables for time of S. There are three consistent observations of S at Δ $=15,000$ kms. for which the tables are scarcely available but were

TABLE VI.

108 *Errors of P for Milne Seismographs in* 1911.

	Distance from Epicentre in kms. 0 — 5000	— 9000	— 10000	— 11000	— 13000		over
Large Errors .	m. +17·2 —	m. +22·1 +16·1	— —	— —	— —	— —	
S	(2) — —	(6) — —	(1) — —	(3) — —	(0) — —	— — —	+10·8? + 9·7? + 8·5?
PR_1 . . .	— — — —	+4·5 +3·3 +2·6 +2·6	+4·4 +4·3 +4·2 —	+6·1 — — —	+6·3 +5·2 +4·9 —	+5·9 +5·7 +5·5 +5 3	+5·2 +5·1 +4·4 +3·9
Doubtful . .	+1·7 +1·2 +1·0 +1·0	+1·7 +1·7 +1·5 +1·5	+1·5 +1·5 +1·0 —	— — — —	+2·8 +2·3 +1·0 —	+3·0 +2·4 +1·4 —	— — — —
+0·9	—	—	—	—	1	—	
+0·8	—	—	—	—	—	—	
+0·7	—	—	—	—	—	—	
+0·6	1	—	—	—	—	—	
+0·5	—	1	—	—	1	—	
+0·4	—	—	1	—	—	—	
+0·3	—	1	1	—	—	—	
+0·2	1	1	2	—	—	—	
+0·1	—	—	—	—	1	1	
0·0	—	1	1	—	—	—	
−0·1	1	—	2	—	—	1	
−0·2	—	2	—	—	—	—	
−0·3	1	1	2	—	—	1	
−0·4	—	—	—	—	—	—	
−0·5	—	—	—	—	—	—	
−0·6	2	3	—	—	—	—	
−0·7	1	—	—	—	—	—	
−0·8	2	1	2	—	—	—	
−0·9	1	1	2	—	—	—	
−1·0	1	—	—	—	—	—	
−1·1	1	—	—	—	—	—	
−1·2	—	—	1	—	—	—	
−1·3	—	—	1	—	—	—	
−1·4	—	—	—	—	—	—	
−1·5	—	1	—	—	—	—	
Large Errors .	−43·0 — —	−3·6 −4·5 −4·7	−4·8 — —	−3·7 — —	— — —	−5·5 — —	

provisionally extended. It seems clear that an even larger correction is necessary at this distance than has been assumed. In calculating the mean error these observations have been omitted, and the mean error is then $\pm 1{\cdot}1$ m. as before. Including them as they stand raises it to $\pm 1{\cdot}2$ m.

Table VII.

36 *Errors for S for Milne Seismographs in* 1911.

	Distance from Epicentre in kms. 0 – 5000	5000 – 9000	9000 – 10000	10000 – 11000	11000 – 16000	All
+2·8 to +3·2	—	—	1	—	—	1
+2·3 to +2·7	—	1	1	—	—	2
+1·8 to +2·2	1	1	—	—	—	2
+1·3 to +1·7	—	—	—	—	—	0
+0·8 to +1·2	—	—	2	1	—	3
+0·3 to +0·7	—	3	2	1	—	6
−0·2 to +0·2	—	1	3	—	—	4
−0·7 to −0·3	—	3	—	1	—	4
−1·2 to −0·8	4	2	—	1	—	7
−1·7 to −1·3	—	1	1	—	(1)	2
−2·2 to −1·8	—	1	—	—	(2)	1
−2·7 to −2·3	—	1	—	—	—	1

In addition there are three large positive errors (+9·9 m., +7·8 m. and +7·8 m.) and four large negative (−5·2 m., −5·8 m., −6·7 m. and −8·1 m.), which may be reflected waves. The percentage is slightly less than before, but, putting 1911 and 1913 together, we have $36+39=75$ tolerably certain S readings as against $47+25=72$, or possibly $64+39=103$ P readings. The fact that S is as often readable as P on Milne seismograms, at any rate for large earthquakes, seems to be thus fairly well established.

VI.—*Comparison of Milne and Galitzin Instruments.*

To the information conveyed by the above discussion the following may be added. At Eskdalemuir Observatory various seismographs have been mounted side by side for comparison, and Mr. G. W. Walker made very careful and thorough comparisons of the relative advantages as indicated in his book already referred to. It seemed desirable at the present juncture to have a formal report on the comparison of the Milne instrument with at least one other; and the Galitzin seemed the best to select as standard of comparison. Application was therefore made to the Superintendent of the Meteorological Office, and he kindly sent the following report, to which the names of L. F. Richardson and L. H. G. Dines are attached.

Comparison between the Milne and the Galitzin types of Seismographs.

It is convenient to treat the question under several different aspects, and a brief description of the two instruments may usefully precede the rest.

It is unnecessary to say much about the Milne instrument. Extreme lightness and compactness characterise it, and no simpler

method of optical registration could well be devised. No expensive lenses are needed, and, with the exception of a few parts of the mechanism, no specially high-class work is required in manufacture. The whole of the apparatus is self-contained and does not take up much floor-space. It does not require a continuously darkened room in which to work. Two pendulums to record both N.S. and E.W. movements can be installed in the same case and record on the same drum.

The Galitzin instrument, on the other hand, is a very much more complicated affair. It is designed to follow a somewhat elaborate mathematical theory, and high-class workmanship and accuracy are needed in its construction. Its pendulum is shorter than the Milne and much heavier—say, seven kilograms. It is hung by two steel wires (Zollner system), and has no pivot at all in some cases. Provision, however, is made on the pendulum and frame for a steel point and cup to be inserted if required. The supporting wires might, with advantage, be made of tungsten if corrosion were feared. At the outer end of the boom are fixed to the frame four powerful horseshoe magnets. Between the poles of one pair of these moves a set of wire coils fixed to the boom and coupled in series with a delicate galvanometer placed in any convenient position elsewhere. Between the other pair is a large copper plate, also fixed to the boom, and this last acts as a magnetic damper. The magnets can be adjusted as desired to vary the magnetic field between the poles.

The galvanometer is of the moving coil type, and has a long period of oscillation when undamped. This galvanometer is an excellent piece of work and is electrically damped so that it can be rendered just aperiodic. With the whole instrument in normal working it is necessary that the undamped periods of both pendulum and galvanometer should be the same, and that they both should be damped just to the limit of aperiodicity.

The optical registration consists of a collimator with a fine slit powerfully illuminated. The beam is reflected from a mirror on the galvanometer and thence to the recording drum, where a cylindrical lens condenses the line of light into a point on the paper.

The two pendulums for recording N.S. and E.W. movements are under entirely separate covers, and in a more refined installation two separate drums are also used; but it is possible to use one drum only and arrange the spots of light from the two galvanometers side by side.

A good deal of floor space is required, and the room in which the recording parts are placed must be kept dark.

The galvanometers and recording drum may be placed in a separate room altogether; and, in fact, are better so placed. The presence of the attendant is likely to disturb the pendulum if he brings his weight near the pillar on which it stands. The recording part of the apparatus is quite unaffected by disturbances in the room in which it is placed.

For a further description of the Galitzin instrument see (1) 'Modern Seismology,' by G. W. Walker, F.R.S., chapters 2 and 3.

(2) The catalogue supplied by H. Masing, St. Petersburg, the makers of the pendulum and recording part of the instrument. (3) 'Ueber ein neues Aperiodisches Horizontalpendel mit galvanometrischer Fernregistrierung,' by Prince B. Galitzin. (4) 'Ueber einen neuen Seismographen für die Vertikalkomponente der Bodenbewegung,' by Prince B. Galitzin. (5) 'Die electromagnetische Registriermethode,' by Prince B. Galitzin, Academy of Sciences, St. Petersburg.

The Galitzin recorder for vertical movements operates electrically in exactly the same manner as the horizontal instrument, and a similar magnetic damper is fitted to it. The room in which the pendulum is placed must be maintained as far as possible at a uniform temperature, as the change in the elasticity of the spring which supports the pendulum causes excessive wandering if the temperature changes by even as little as 0.5 per cent.

Comparative cost.—A Galitzin installation is much more expensive than a corresponding Milne one. Two horizontal pendulums complete with galvanometer and one recording drum cost at least 148*l.*, while the pendulum for vertical movements with galvanometer and drum costs at least 110*l.*

This does not exhaust the expensiveness of the instruments, since about six times as much sensitive paper is required for one Galitzin recording drum as for one modern Milne drum for two pendulums. It is customary to run the paper at three centimetres per minute, and unless the optical arrangements were improved it would be hardly feasible to run it at much less speed without losing a good deal. Under these circumstances the cost in paper alone of one recorder is about 33*l.* per annum.

Attention required.—The Milne instrument does not require more than ordinary skilled attention. If the operator be used to handling delicate instruments little more is required. Of the Galitzin instrument the same may be said as far as the ordinary routine is concerned, but the greater complexity of the apparatus means a greater number of things liable to go wrong, and sooner or later it is almost certain to happen that highly skilled attention is necessary. Both types of instrument require periodical standardisation, but while in the Milne type this is quite a simple process, in the Galitzin it is quite otherwise. A certain amount of auxiliary apparatus is required, such as telescopes and scales, and two persons are necessary to make simultaneous observations of the pendulum and galvanometer; when these have been made the constants of the instrument can be determined. Prince Galitzin has worked out formulæ for this purpose.

The whole process has in general to be gone through twice for each instrument, and it is a lengthy operation, taking probably about two working days. A certain measure of observational skill is required to take the necessary readings accurately, as well as a fair working knowledge of mathematics to deal with the results when obtained.

It would be possible to simplify the process somewhat more than has at present been done, and reduce it largely to routine; but

a Galitzin installation must always require a greater measure of skilled attention to run it successfully than is the case with the simpler types of instruments.

It is difficult to estimate what is the minimum of mathematical and physical knowledge that must be possessed by an assistant in order to maintain successfully a Galitzin installation. A working knowledge of algebra is essential, and probably with this as a basis an intelligent operator could learn the rest of the routine with the aid of computing-forms. But without a knowledge of higher mathematics, and particularly elementary differential equations, it is impossible to understand the meaning of the formulæ by which the constants are determined.

Results obtainable.—The Milne type of instrument is very sensitive as a mere seismoscope. With the exception of very faint movements indeed, some record of a distant quake can always be obtained by it; this is due to the absence of damping and almost entire absence of solid friction; by altering the period of oscillation of the boom it can be made particularly sensitive to any wave-period desired. The instrument at Eskdalemuir Observatory has at present a period of about eighteen seconds, and this corresponds approximately with the wave periods from very faint and remote shocks. For waves of this type the Milne instrument leaves some record of almost any earthquake that affects the Galitzin instrument; but whereas the latter gives a trace that approximately follows the actual movements of the ground, the trace from the former has little resemblance to it. Maximum movements on the Milne record may or may not coincide with the maximum movements of the ground: it depends on the type of the earth movements and on the period of the pendulum. By damping slightly, a more faithful record can be obtained, and by making the pendulum actually dead beat a moderately close agreement will prevail between the actual earth movements and those worked out from the record. This can be established theoretically, but Prince Galitzin has also conducted experiments which show that theory and practice are in close agreement. See Professor C. G. Knott's book on 'The Physics of Earthquake Phenomena,' chapter 5, Unfortunately the reduction in the scale of the record which accompanies damping renders the Milne pendulum very insensitive when damped. For some months an oil damper has been fitted to one of the Milne pendulums at Eskdalemuir; the ratio of successive elongations is approximately 2:4. The results obtained are disappointing for the reason given above.

If any satisfactory means could be found of increasing the magnification optically even by a moderate amount, the damped Milne pendulum should be capable of yielding good results, and the greater simplicity of standardisation should be another point in its favour.

Turning to the Galitzin type of machine, as an instrument of precision it may safely be said to be ahead of all others. The interpretation of its records is not a very simple matter, but by those prepared to spend the time a vast amount of information can be

obtained. The scale of magnification varies widely with different wave-periods, being in general approximately 800 as a maximum and for periods of about fourteen seconds, and falling off for either longer or shorter periods.

The preliminary tremors of a distant earthquake can be examined particularly well, and individual impulses analysed. An experienced observer can analyse these preliminary phases from the shape and general appearance of the record far more easily than can be done in the case of the undamped Milne record. See 'Modern Seismology,' by G. W. Walker, F.R.S., chapter 7, for fuller information on this point.

It is probably safe to say that a full and rigid investigation into the theory of these instruments has not yet been published, and the possibilities of deducing complicated formulæ in that direction are vast. The high degree of accuracy that in favourable circumstances has been obtained in locating epicentres, using the records from a single station only, is sufficient to demonstrate the excellence of the instrument as at present used. It would be well to state here that, though the Galitzin record does not represent the ground motion accurately in many cases, yet in the case of the first movement of the first phase P of an earthquake the movements on the N.S. and E.W. records will be proportional to the actual earth movements provided that the two pendulums and galvanometers are in correct adjustment and have the same undamped period. Hence the azimuth can in favourable circumstances be accurately and easily determined, though to work out the actual earth movements would be a complicated matter.

One point worthy of mention in which the Galitzin instrument differs from most or perhaps all others is the absence of trouble arising from the wandering of the pendulum. However the latter may wander, the zero of the galvanometer is unaffected. The scale value may be altered slightly if the pendulum be far from the middle position, but this can easily be corrected from time to time. This quality renders the instrument useless for determining slow changes in tilt, as can be done with other types.

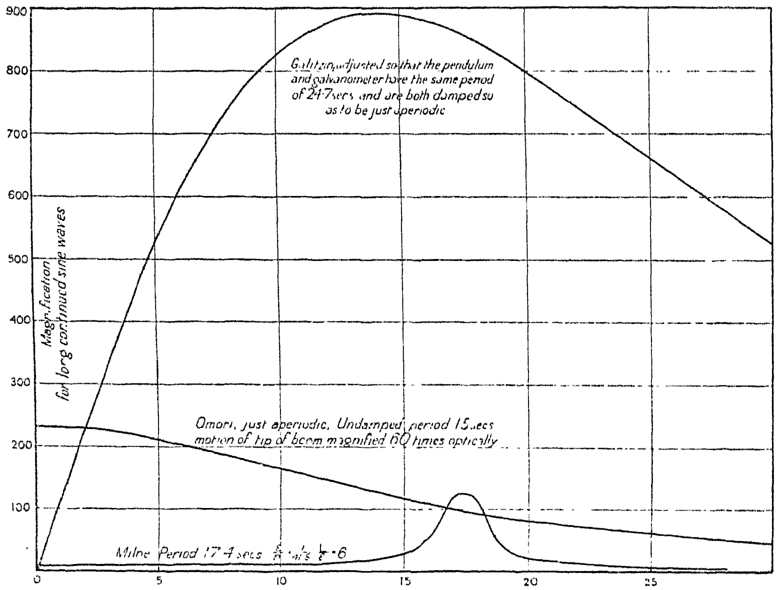
Mention has been made above of varying scale value; this introduces another limitation. For very short periods the magnification is very small, being about 110 for one-second period and varying directly as the period for lesser values.

Hence rapid vibrations will leave no record, and this may be the explanation of the fact that small local earthquakes are not recorded on this type of instrument.

Owing to the high degree of magnification and great sensitivity, some trouble is experienced from disturbances due to high winds, and from experience at Eskdalemuir it would seem desirable to house the pendulum in a small sheltered building rather than a large exposed one. Heavy weights moving in the vicinity cause trouble, as with any other sensitive instruments; but the records so produced being of definite character can be readily traced to their origin, and are immaterial if not

too frequent. Occasional traffic along a neighbouring road would not cause much confusion on the record.

A curve is shown attached giving the magnification of movement in both the Milne and Galitzin types. It refers solely to the case



of a long-continued series of uniform waves; but it is noteworthy that in the Milne type it cannot be applied to any other kind of motion and may be considerably in error even one or two minutes after the commencement of the series.

In the Galitzin type, however, the free motion dies away much more rapidly.

VII.—*Present Value of the Milne Instrument.*

We may summarise the present situation as follows:—

(*a*) The Milne instrument is undamped, but for one purpose—viz., the determination of times of arrival of P and S—this does not matter. There has been an idea that S (or P_2) is not easy to read on Milne records; but S has often been read in mistake for P, and when these readings are counted properly S seems to be identifiable as often as P. On the other hand, the absence of damping makes the readings of maximum of uncertain significance.

(*b*) The time scale of the Milne instrument is small and its magnification is also small. Both might be increased with advantage, and it seems probable that then the times of arrival of P and S could be read as well as on most other instruments.

(*c*) The present wide dispersion of Milne stations makes the records of great value. Most of the modern instruments are in Europe. For

an earthquake in Europe they are distributed in various azimuths (not quite a complete circuit even then), but for distant quakes they cluster in the same azimuth and give no material for discussion in azimuth (see Section VIII.). The Milne stations, however, especially those in Australia, can supply this information.

It is clear, then, that the usefulness of the Milne instruments is by no means at an end, as the perfection of modern seismographs (especially the Galitzin instrument) might at first suggest. And it should not be difficult to extend it considerably.

(*a*) It can be *damped* effectually. Mr. J. J. Shaw, of West Bromwich, has done this electro-magnetically with an aluminium plate in place of the Galitzin copper plate, which is too heavy for the light Milne boom. At present, however, he has not obtained simultaneously sufficient magnification to give the damping effect: damping is chiefly of use for following the movements of the long waves, and the scale should be big enough to show them clearly. Mr. Shaw is still at work on the instrument, and hopes to obtain the requisite magnification.

(*b*) There should be little difficulty in increasing the magnification moderately both in movement and in time scale, though it may not be easy to settle which is the very best way of doing it. The experiments being made by various observers should at least give us a feasible plan.

(*c*) Meanwhile *if special attention is paid to getting good time determinations*, and if the films are carefully read with a lens, the times of arrival of P and S for Milne stations should enable us to correct the tables for considerable distances from the epicentre where the European stations all agree and are all in error owing to their congestion in azimuth. (See next Section.)

VIII.—*Correction of the Tables for P and S.*

Recurring to the discussion of Section IV., it was shown that the tables for both P and S were sensibly in error, and the question arises how far they can be corrected. The main facts are these:—

(α) The tables for small values of Δ are sensibly correct. This is shown by the agreement of determinations of epicentres from Pulkovo and Eskdalemuir, quoted by G. W. Walker in his monograph (p. 65). From each station the azimuth a and the distance Δ can be determined; and from the two azimuths a and a_2 the epicentre can be determined without reference to Δ at all.[1] This is a modern advance, the importance of which is not easily over-estimated. If then the values of Δ determined from the P and S tables agree (to a fraction of a degree) with those found from the azimuths, the tables must be fairly correct. The value of Δ is about 20°.

(β) But this single example may give quite a wrong impression of the accuracy with which an epicentre is at present determined. At greater distances we gradually lose the accordance between these stations. Thus, on January 4, 1912, Pulkovo gives 175° E., 49°·5 N., and Eskdale-

[1] See letter of Galitzin and Walker in *Nature* for September 5, 1912.

muir 177° E., 51° N.; on July 9 Pulkovo gives 30°·3 E., 2°·1 N., and Eskdalemuir 33°·9 E. and 5°·3 N.; and at greater distances still the discordance may be 5° or even 10°. The azimuths may still be good, though as the azimuthal lines do not meet so sharply, the determination becomes less definite; and, moreover, it must be remembered that actual errors in the adjustment of the booms become of greater importance. We have nothing to set against the clear evidence offered in Section IV. that the tables for S are in error, though since the errors there found are only *relative,* we may add a constant to them all, substituting, for instance, for

Error at	15°	35°	55°	75°	95°	115°
	m.	m.	m.	m.	m.	m.
	—0·3	—0·1	+0·1	+0·3	+0·5	+0·7
the revised values						
	0·0	+0·2	+0·4	+0·6	+0·8	+1·0

so that the error is small near the epicentre.

Similarly the errors for P might be written—

Error at	15°	35°	55°	75°	95°	115°
	m.	m.	m.	m.	m.	m.
	0·0	0·0	+0·1	+0·2	+0·4	+0·6

if we determine to keep the error small near the epicentre. In this case it seems possible that the revised tables just published by the K.G. Landesantalt für Meteorologie und Geodynamik in Zagreb (Agram) might supply information which would determine the unknown arbitrary constant. The errors of the Galitzin tables indicated by Zagreb at the above points are

	m.	m.	m	m.	m.	m.
	+0·1	+0·1	0·0	+0·1	+0·2	+0·3
Difference	+0·1	+0·1	—0·1	—0·1	—0·2	—0·3

The differences do not, however, remain constant, even approximately. The present comparison indicates larger errors for values of Δ greater than 75° than the Zagreb tables admit.

It thus appears that the moment is not yet come to suggest corrections to the tables which are likely to meet with general acceptance. It seems better to retain the old tables until a much greater mass of material has been discussed, and the old tables will accordingly be used for the comparisons made at Shide at any rate for the observations of 1914. The discussion of some 100 earthquakes should provide corrections approximating to definitive ones. Meanwhile, the best available corrections to the tables from the material above discussed, incorporating the information derived from the next section, are given at the end of the next section.

IX.—*Discussion in Azimuth.*

If the receiving stations are arranged in azimuth (A) round the epicentre, then

(*a*) Assuming the velocity of transmission constant in all azimuths, any error (δ) of position of the epicentre will give rise to an error

$$c + e \cos (A - A_0)$$

in the observed times at the stations: where A_0 is the azimuth in which the epicentre is erroneously displaced; A is the azimuth of the receiving

station; c is the effect of the displacement (δ) on P or S, as the case may be, at the distance of the receiving station; and c is a constant depending on the position of Pulkovo, or other station from which the epicentre is determined.

(b) If the velocity of transmission varies with the azimuth, then, if the velocity in azimuth A is not the same as in azimuth A + 180°, there will be a first-order harmonic which will be mixed up with that just written, due to the error in position of epicentre; and it may be difficult to separate the two. If, however, the velocity is the same for A and A + 180°, then we may look for a second-order harmonic to represent the variation. It will be seen from what follows that there are no trustworthy indications of such terms from the material now discussed. The material is insufficient to pronounce definitely against the existence of such terms, especially with small coefficients; but it is apparently sufficient to discredit any large term of the kind. For instance, Milne suggested a velocity N. and S. sensibly less, in the case of the large waves, from the velocity E. and W. (Eighteenth Report, § v). No such difference can be detected in the velocities for P and S.

We will first give in some detail the results for a single earthquake, that of 1913, January 11, adopted epicentre 6° N., 117° E. The residuals for P, when corrected for distance from epicentre as in Section IV., and arranged in azimuth measured from the N. point round the epicentre in the direction N., E., S., W., are as shown in Table VIII.

We see at a glance the better distribution of the Milne pendulums; most of the modern pendulums are in Europe and appear in the same azimuth-class 300°—330°. Were it not for the Milne instruments we should have very scanty material for an azimuth discussion; and yet this is one of the most favourable cases. The inferiority of the Milne instrument suggests giving a smaller weight to its records, but it will be seen that we should gain very little thereby. Taking the simple means as in the last column and filling in vacant terms by simple interpolation (in brackets), we can make a very rough harmonic analysis, obtaining

$$-1{\cdot}6 + 7{\cdot}5 \cos (\mathrm{A}-330^\circ) + 2{\cdot}7 \cos 2\,(\mathrm{A} - 70^\circ).$$

Treating the S observations in the same way, we get Table IX.

The material for discussion in azimuth is even more scanty and uncertain than before; but, analysing it for what it is worth, we get

$$-\,1{\cdot}2 + 8{\cdot}0 \cos (\mathrm{A} - 332^\circ) + 4{\cdot}7 \cos 2\,(\mathrm{A} - 177^\circ).$$

Now, considering the nature of the material and of the process used, it is somewhat remarkable that the results from P and S should accord so well in indicating a correction to the epicentre. The direction is in azimuth 331° say, and as the azimuth of Pulkovo is 330°, it is pretty clear that the estimated Δ for Pulkovo is in error, owing doubtless to the errors of the tables. The *amount* of displacement is not so easy to assess. In the above simple process we have treated all stations, at whatever distance from the epicentre, alike. A displacement of the epicentre of 1° will, however, alter the times of arrival of P by 16 s. near the epicentre, by 5½ s. at 90°, and by less still at greater distances. Nevertheless, on calculating the alterations for the actual distances, the mean

TABLE VIII.

Distribution of errors of P in azimuth round epicentre, 1913, January 11.

(The unit is 0·1 m. or 6 secs.)

(*a*) *Instruments other than Milne.*

0° — 30°	— 60°	— 90°	— 120°	— 150°	— 180°	— 210°	— 240°	— 270°	— 300°	— 330°	—360°
+ 4 + 3 − 4				− 12	+ 1		0			+ 17 + 7 + 7 + 6 + 4 + 4 + 4 + 3 + 2 + 2 + 1 − 5 − 6	+ 3

(*b*) *Milne Instruments.*

0° — 30°	— 60°	— 90°	— 120°	— 150°	— 180°	— 210°	— 240°	— 270°	— 300°	— 330°	—360°
+ 11		− 1		− 9 − 12	− 16	− 13	0	+ 3	+ 9 + 5 + 2	+ 14 − 9	
+ 4	(+ 2)	− 1	(− 6)	− 11	− 8	− 13	0	+ 3	+ 5	+ 3	+ 3

TABLE IX.

Distribution of errors of S in azimuth round epicentre, 1913, January 11.

(The unit is 0·1 m. or 6 secs.)

(*a*) *Instruments other than Milne.*

0° — 30°	— 60°	— 90°	— 120°	— 150°	— 180°	— 210°	— 240°	— 270°	— 300°	— 330°	—360°
+ 15 + 5					+ 3		− 16 − 5 − 5			+ 13 + 11 + 4 + 4 − 1 − 1 − 3 − 5 − 7 − 8	+ 11
(*b*) *Milne Instruments.*											
− 5				− 10 − 16 − 20					+ 6	+ 23 − 8 − 18	+ 22
Mean + 5	(0)	(−5)	(−10)	− 15	+ 3	(−3)	− 9	(−2)	+ 6	0	+ 16

for the different groups was found to be nearly constant at about 8 s. Since the coefficient (8 units of 0·1 m.) means 48 s., we may take it that the epicentre is about 6° wrong. As regards direction, note that the observed times for receiving stations on the side of the epicentre remote from Pulkovo are too small; so that the epicentre must be moved nearer to them and further from Pulkovo. The observed S–P at Pulkovo, viz. 10 m. 24 s., does not correspond (as indicated by the present tables) to an epicentral distance of 83°·5, but to a distance of 89°·5.

Turning to S, we find the average value of 1° to be about 13 s. The first harmonic of S thus indicates a displacement of 48°/13 or 3°·7. We may regard this as a satisfactory confirmation of the magnitude of the error, which may be put at about 5°.

The second harmonics in both cases are small, and the phases are quite discordant. We may fairly say that there is no evidence of a variation in velocity of an elliptic type.

As regards other earthquakes analysed for azimuth the following notes will suffice :—

1913, *March* 14. *Epicentre* 11° *N.*, 123° *E.*, *distant* 82° *from Pulkovo.*

Of nearly same type as that of 1913, January 11, but distribution of stations not so good. The numbers in the 30° divisions for P are

1 1 0 0 1 2 1 1 1 4 33 5

and the harmonic expression is (in units of 0·1 m.)

$$+0{\cdot}2+5{\cdot}0\cos(A-302^\circ)+4{\cdot}0\cos 2(A-36^\circ).$$

For S the number of stations are

1 1 0 0 0 6 0 0 0 2 24 3

and the harmonic expression is

$$-7{\cdot}8+14{\cdot}5\cos(A-345^\circ)-4{\cdot}2\cos 2(A-7^\circ).$$

In spite of the broken nature of the series, the indication of an error of about 4° or 5° in Δ is tolerably plain. The azimuth of Pulkovo is 330°, and the magnitudes of the displacement assigned by the P observations may be put at 30°/8 = 3°·8.

„ S „ „ „ 87°/13 = 6°·7.

There is some indication of a second order term, but it cannot be regarded very seriously.

1913, *March* 23. *Epicentre* 26° *N.*, 143° *E.*, *distant* 78° *from Pulkovo.*

The only available observations between azimuths 0° and 210° are two Milne observations of P and one Milne of S. There seems no advantage in making even a rough estimate.

1913, *April* 30. *Epicentre* 50° *N.*, 176° *E.*, *distant* 67° *from Pulkovo.*

Number of observations in the separate groups

for P	4	2	0	0	1	0	0	0	3	1	3	14
for S	4	3	1	0	0	1	0	0	1	2	1	10

Harmonic expressions

from P $+2\cdot1+2\cdot7\cos(A-207^\circ)+3\cdot6\cos2(A-73^\circ)$

from S $+0\cdot5+11\cdot0\cos(A-235^\circ)+2\cdot6\cos2(A-160^\circ)$

Azimuth of Pulkovo being 342°, the mean direction of displacement (azimuth 220° say) is nearly at right angles to the direction of Pulkovo, and cannot be wholly explained by an error of tables. The small component in the line joining epicentre to Pulkovo is in the opposite direction to that previously noted.

1913, *June* 14. *Epicentre* 43° *N.*, 26° *E.*, *distant* 17° *from Pulkovo.*

There are unfortunately no observations of S from azimuth 90° to 270°, so that we cannot make any analysis. The mean results for the other azimuths are

Azimuth	270°—300°	—330°	—0°	—30°	—60°	—90°
Mean	+1	−4	−2	−4	+4	0
No observations	4	4	11	2	2	1

which suggest a displacement in the opposite direction to that of January 11 and March 14, and in the same direction as the component of April 30.

The numbers for P are

1 4 1 2 0 0 1 0 4 3 11 2

and the harmonic expression is

$$+2\cdot1+2\cdot8\cos(\theta-165^\circ)+1\cdot6\cos2(\theta-111^\circ)$$

The azimuth of Pulkovo being 7°, the small displacement indicated is nearly radial and in the opposite direction to those of January 11 and March 14.

Hence, so far as this evidence goes, the error of S–P is about 30 s. at 85°, diminishes at lesser distances, and changes to a small negative value. The corrections needed by the Galitzin tables would seem to be approximately as follows:—

	$\Delta =$	15°	25°	35°	45°	55°	65°	75°	85°	95°	105°
		s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
Correction	P =	0	0	0	0	0	−1	−3	−8	−15	−24
Correction	S =	+5	0	−4	−8	−11	−14	−17	−24	−35	−50
Correction	(S–P) =	+5	0	−4	−8	−11	−13	−14	−16	−20	−26
Correction	Δ =	−5	0	+6	+13	+18	+24	+28	+31	+42	+52

the correction to Δ being expressed in units of 0°·1.

Investigation of the Upper Atmosphere.—Thirteenth Report of the Committee, consisting of Dr. W. N. SHAW (*Chairman*), Mr. E. GOLD (*Secretary*), Messrs. C. J. P. CAVE *and* W. H. DINES, Dr. R. T. GLAZEBROOK, Sir J. LARMOR, Professor J. E. PETAVEL, Dr. A. SCHUSTER, *and* Dr. W. WATSON.

A MEETING of the Joint Committee was held in the rooms of the Royal Meteorological Society on May 5, 1914. It was decided to allocate the grant from the British Association towards the expense of investigations with pilot balloons over the ocean to be undertaken by the Secretary on the journey to Australia, *via* the Cape of Good Hope. An

additional grant was made from the funds of the Royal Meteorological Society to enable simultaneous observations to be made by Dr. W. Rosenhain, of the National Physical Laboratory, on the journey *via* the Suez Canal. A report on the observations is in preparation and will be published in due course.

The report by Mr. G. I. Taylor on the observations which he made on board the *Scotia* in 1913, referred to in the Committee's report last year, has been published in the official account of the results of the *Scotia* Expedition, issued by the Board of Trade. The results which Mr. Taylor obtained throw much light on the formation of fog and on the propagation of heat through the atmosphere by means of eddies. He found generally that thick fogs were associated with a large increase in the temperature of the air in a vertical direction, while light fogs occurred when the increase was small.

The Committee records with regret the death during the year of Mr. Douglas Archibald, who was one of the earliest investigators of the upper air by means of kites, and had served on the Committee since its appointment at Glasgow in 1901.

The Committee asks for reappointment, with a grant of 25*l.*

Radiotelegraphic Investigations.—Interim Report of the Committee, consisting of Sir OLIVER LODGE (*Chairman*), Dr. W. H. ECCLES (*Secretary*), Mr. SIDNEY G. BROWN, Dr. C. CHREE, Professor A. S. EDDINGTON, Dr. ERSKINE-MURRAY, Professors J. A. FLEMING, G. W. O. HOWE, *and* H. M. MACDONALD, Sir H. NORMAN, Captain H. R. SANKEY, Professor A. SCHUSTER, Dr. W. N. SHAW, *and* Professor S. P. THOMPSON.

THE past year has been occupied mainly by the designing, printing, and distribution of books of forms for recording observations, by the enrolment of observers, and by the preliminary work in connection with the observations to be made during the forthcoming solar eclipse.

I. *Collection of Ordinary Daily Statistics.*

We have obtained the cordial support of many Government Departments of the British Empire and of other countries. In the British Empire the Navy has taken forms sufficient to distribute to about 120 ships. The Post Office has sent forms to nine stations. The Government of Canada have undertaken to get statistics from four stations on the Pacific Coast. The South African Government have authorised the collection of statistics at Cape Town and Durban. The Australian Government have brought eight stations into the scheme, and the New Zealand Government and the Indian Government each several stations. The Colonial Office has kindly circularised other of the Colonies, and of these the following have already replied favourably, and have had supplies of forms despatched to them:—

Falkland Islands.	Zanzibar.	British Guiana.
Bahamas	Somaliland.	Jamaica.
Trinidad.	Fiji.	Sierra Leone.
Ceylon.	Gold Coast.	

The Government of Norway have agreed to have statistics collected at four stations; the United States Government at five; in Germany the Telegraphs Versuchsamt is making observations at Berlin, and there are some Russian Government stations likely to co-operate.

The following Companies are taking a prominent part in the collection of statistics: The Marconi International Marine Communication Company, Ltd., have already twenty-three ships at work; the Marconi Company of Canada have thirteen stations at work on the East Coast of Canada, in Newfoundland and on the Great Lakes; the American Marconi Company have put fifteen land stations (between Alaska and the Gulf of Mexico) to work, and several ships; the Federal Wireless Telegraph Company of America have started observations at their San Francisco station; the Gesellschaft für drahtlose Telegraphie will put a considerable number of stations to work as soon as forms have been translated, and they have the intention of establishing a small prize scheme amongst their operators for the best series of observations. At the Slough station the Anglo-French Wireless Company started observations which will be continued by the Galletti Company; while the English Marconi Company are doing the like at Chelmsford.

With regard to Russia, the language difficulty was likely to prove formidable, but the Editor of the Russian 'Journal of Wireless Telegraphy' has arranged that the forms be translated into Russian and that the collection of statistics be urged upon readers of his Journal. The Société Russe de Télégraphes et Téléphones sans Fil have agreed that the forms, when translated, shall be used at a number of the stations under the control of the Company in Russia.

Among private experimenters of note we have obtained the support of several gentlemen abroad, who will doubtless have to be mentioned in subsequent reports. There are also a number of Professors in the British Isles and in the Colonies helping, and about sixty-one amateurs. Of these there are thirty-six in England, two in Scotland, six in Ireland, and one in Wales.

A considerable number of completed forms have already come to hand and a start has been made on the analysis.

II. *Observations to be made during the Eclipse of August* 21, 1914.

The central line of the eclipse passes across Norway, Sweden, the Baltic, Central Russia, the Black Sea, and Persia, to the coast of India. Accordingly, the Governments of Norway, Sweden, Russia, and India have been approached. The Norwegian Government have generously placed practically all their stations at the disposal of the Committee; the Swedish Government have agreed that the observations they wish to make on their own behalf shall be made in accord with the programme of the Committee, to whom copies will be supplied; and the Russian Government will set a number of stations to work, but the number and position of these have not yet been settled. The Société Russe will place their high-power station at St. Petersburg at the disposal of the Committee, and the Gesellschaft für drahtlose Telegraphie is also willing to allow two or three large stations to come into the scheme. This

Company will enact that observations on the day of the eclipse shall be compulsory in many of its stations in the Baltic and in Germany. The Indian Government have agreed to help also. In Western Europe the transmission of special signals is not of such great importance as in the districts nearer the central line of the eclipse, but some observations ought to be instituted on signals in that part of the world. The Marconi Company have kindly expressed their willingness to aid the Committee by transmitting from certain high-power stations a few special signals, if desired, at times to be arranged by the Committee.

Many private observers in different parts of the world have signified their willingness to make a special effort on the day of the eclipse. It has been explained to the authorities in the United States, Canada, Australia, South Africa, and New Zealand, that although there is not much likelihood of the effects of the eclipse being perceived in their territories, yet they will be advised of the programme of the Committee, in order that they may, if they will, determine precisely whether there is, or is not, any effect. Since it seemed important to enlist the sympathies of as large a number as possible of skilled observers on the Eastern boundaries of Germany, Austria, and Hungary, the Editor of the 'Jahrbuch für drahtlose Telegraphie' was asked, and has agreed, to seek German-speaking observers, conduct all preliminary correspondence with them, translate forms and get them printed and distributed, and to collect the forms. It has recently been arranged that a large proportion of this work may be shared with the International Commission of Brussels.

In addition to all this welcome assistance, we are especially glad to report that the Board of the Admiralty have agreed to co-operate on an extensive scale.

The Relations between this Committee and the International Commission of Brussels.

As a member of the British Section of the International Commission, the Secretary was made a delegate to the recent Conference in Brussels, and there suggested that it might be to the advantage of both organisations, especially when requesting assistance from Government Departments or Companies, or even private experimenters, that a public announcement should be made showing that the aims of the two bodies are different, that there is room for both, that there is little danger of any Government or Company or private experimenter being asked to do the same thing twice, or to favour one to the detriment of the other; and that if on any occasion there were overlapping, then the two organisations should endeavour to co-operate. The International Commission therefore drew up and passed the following resolution:—

'La Commission Internationale de T.S.F.S., ayant pris connaissance du but des travaux du "Committee for Radio-telegraphic Investigation of the British Association," estime que les travaux des deux organisations ont des objets différents.

'La Commission Internationale de T.S.F.S. se propose, en effet, de faire des recherches qui portent principalement sur les mesures quantita-

tives se rapportant à l'émission, à la propagation et à la réception des ondes électriques.

'L'Association Britannique a décidé, de son côté, de recueillir, de classer et de commenter les résultats des observations susceptibles de faire ressortir les relations entre les phénomènes géophysiques et la propagation des ondes électriques. Il entre également dans ses vues de dresser la statistique et de faire l'étude des phénomènes anormaux et des perturbations atmosphériques.

'En conséquence, si les champs d'activité des deux organisations viennent à avoir des points communs, la Commission Internationale de T.S.F.S. engage ses adhérents à prêter éventuellement le concours le plus complet à la "British Association."'

At a meeting of the British Association Committee on May 8, 1914, the following resolution was adopted:—

'That the Radiotelegraphic Investigation Committee of the British Association for the Advancement of Science take cognisance of the resolution adopted by the Commission Internationale de Télégraphie sans Fils Scientifique at the recent conference in Brussels, and desire to affirm that they find themselves in full accord with the definitions, as expressed in the resolution, of the differences between the aims and methods of the researches promoted by the two organisations; while, in regard to those researches in which the two bodies both take an active interest, this Committee warmly welcome and value highly the offer of co-operation, and gladly undertake to give all assistance in their power.'

The Committee has expended up to the present in office expenses, printing, and distribution of forms, the sum of 144*l.*

[NOTE.—The following communication was circulated to Members of the Committee by the Secretary on behalf of the Chairman in December, 1914:—

The war has naturally had a very direct effect on radiotelegraphic investigations. About August 1 last, private wireless telegraph stations throughout the Empire were nearly all dismantled or taken possession of by military authorities, while naval and other Government stations stopped all merely scientific observing. The radiotelegraphic stations in Russia, Germany, and neighbouring countries doubtless discontinued the filling up of our forms as soon as mobilisation began. A few stations in India, Australia, Canada, the West Indies, and the United States are, however, still at work. In the last-named country about thirty stations are making observations.

The Committee's programme for the collection of statistics three days a week in all parts of the English-speaking world and in a few other countries was planned to embrace one complete round of the seasons. The fact that the programme has been interrupted after only three months of really full work diminishes greatly the scientific value of such statistics as have been collected. It also implies considerable financial loss. A large batch of forms was distributed to our Navy in July: in clearing for action these forms would probably be wasted. The German edition was distributed in June. The Russian edition also was probably distributed before the outbreak of war.

The extensive scheme of special observations projected for the occasion of the solar eclipse failed almost completely in the countries in which the eclipse was visible. A small amount of work was done in Norway and Sweden. All the necessary forms had been printed, and some had been circulated before the war started. The financial loss to the Committee in this respect exceeds a hundred pounds.

The day-by-day statistics collected in the period April to July are now being analysed. The conclusions drawn from these observations will, it may be hoped, have some scientific value of their own, and in any case they should yield information which may guide the Committee, when the time comes, to further attacks on the problems concerned. A similar thought may be set down as consolation for the eclipse failure.

In October last, at a special meeting summoned by the Inspector of Wireless Telegraphy at the General Post Office, where it happened that the Committee were represented by Dr. Erskine-Murray and the Secretary, the Committee were asked to draw up for the Home Office a list of gentlemen distributed over the British Isles who would be willing, if and when called upon, to assist the police by acting as voluntary experts in wireless telegraphy. The police cannot in general be expected to possess sufficient technical knowledge to discriminate between dangerous radiotelegraphic apparatus and other apparatus. Co-operation with the police authorities in each locality by someone possessing technical knowledge will help to prevent blunders and may assist in detecting illicit traffic. Accordingly gentlemen whose names appear in the address book of the Committee have been written to, and lists of voluntary experts have been supplied to the Home Office.]

Establishing a Solar Observatory in Australia.—Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Dr. W. G. DUFFIELD (*Secretary*), Rev. A. L. CORTIE, Dr. F. W. DYSON, *and* Professors A. S. EDDINGTON, H. F. NEWALL, J. W. NICHOLSON, *and* A. SCHUSTER, *appointed to aid the work of Establishing a Solar Observatory in Australia.*

THE Committee records with great sorrow the death of its former Chairman Sir David Gill, whose name has always been so prominently associated with scientific enterprises connected with the Southern Hemisphere. Professor H. H. Turner has been appointed Chairman in his place.

The Secretary has great pleasure in reporting that the following letter has been received from the Commonwealth Authorities in response to further representations regarding the desirability of erecting a Solar Observatory within the Commonwealth:—

Commonwealth Offices,
72 Victoria Street, Westminster, S.W.
March 10, 1914.

Dear Dr. Duffield,

With reference to previous correspondence in regard to the establishment of a Solar Observatory in Australia, I desire to inform you that I have now received a memorandum from the Commonwealth Government advising that in the scheme for the organisation of services in connection with the Seat of Government at Canberra, provision has been made for the establishment amongst general astronomical studies of a section to be devoted to solar physics in particular.

Yours sincerely,
(Signed) R. MUIRHEAD COLLINS.

Dr. Geoffrey Duffield,
University College, Reading.

The Committee records its great satisfaction at the promise of the

institution of Solar Research in Australia—an end for which it has worked since its appointment at the Dublin Meeting of the Association in 1908. The Prime Minister of the Commonwealth has consented to receive a deputation of overseas astronomers with regard to the nature of the solar work which should be undertaken in Australia.

The Calculation of Mathematical Tables.—Report of the Committee, consisting of Professor M. J. M. HILL *(Chairman)*, Professor J. W. NICHOLSON *(Secretary)*, Mr. J. R. AIREY, Professor L. N. G. FILON, Sir GEORGE GREENHILL, Professor E. W. HOBSON, Professor ALFRED LODGE, Professor A. E. H. LOVE, Professor H. M. MACDONALD, *and* Professor A. G. WEBSTER.

THE grant given to the Committee during the past year has been expended on the calculation of the Logarithmic Bessel Functions, for which it was specially allocated. In the present report are Tables of the functions $Y_0(x)$ and $Y_1(x)$, whose significance was explained on page 29 of the last report. These proceed from argument $x = 0{\cdot}02$ to $x = 15{\cdot}50$, at intervals of 0·02, and are correct to six significant figures.

Some further Tables of the functions $G_n(x)$ are also included, for varying order n of the functions. These are incomplete at present. The Committee is proceeding with the further calculation of the functions $Y_2(x)$, $Y_3(x)$, ... on the same scale as the present Tables of Y_0 and Y_1.

The Committee desires to ask for a further grant of 30*l.* during the coming year, to be allocated to this work.

Some Tables calculated by Mr. Doodson, of the University of Liverpool, are given at the end of the report. They deal with the functions of type $J_{n+\frac{1}{2}}(x)$, where n is a positive or negative integer. A considerable demand for these Tables exists at present. Mr. Doodson is continuing this work, and it is suggested that his name be added to the Committee. The previous requisition that a large number of copies of the report (about 100) should be placed in the hands of the Secretary for distribution is repeated, as the demand for these Tables from physicists is increasing.

Tables of the Neumann Functions $Y_0(x)$ *and* $Y_1(x)$ *or Bessel Functions of the Second Kind.*

The second solution of Bessel's differential equation

$$x^2 \frac{d^2y}{dx^2} + x\frac{dy}{dx} + (x^2 - n^2) \cdot y = 0$$

has been given in several forms—$G_n(x)$, $Y_n(x)$, $K_n(x)$, &c. Tables of $G_0(x)$ and $G\ (x)$ for values of x from 0·01 to 16·00 by intervals of 0·01 were published in the report for 1913.

Short Tables of the $Y_0(x)$ and $Y_1(x)$ functions defined by

$$Y_0(x) = J_0(x) \cdot \log_e x + \left(\frac{x}{2}\right)^2 - (1 + \tfrac{1}{2})\left(\frac{x}{2}\right)^4 \Big/ 2\,!^2 + (1 + \tfrac{1}{2} + \tfrac{1}{3})\left(\frac{x}{2}\right)^6 \Big/ 3\,!^2 - \ldots.$$

$$Y_1(x) = J_1(x)\,.\,\log_\epsilon x - J_0(x)/x - \frac{x}{2} + (1+\tfrac{1}{2})\left(\frac{x}{2}\right)^3/1!\,2!$$
$$- (1+\tfrac{1}{2}+\tfrac{1}{3})\left(\frac{x}{2}\right)^5/2!\,3! + \dots$$

have been calculated by B. A. Smith for $x = 0{\cdot}01$ to $1{\cdot}00$ and $1{\cdot}0$ to $10{\cdot}2$ to four places of decimals, and by J. R. Airey for $x = 0{\cdot}1$ to $16{\cdot}0$ to seven places.

The following Tables have been computed from the relation

$$Y_n(x) = (\log 2 - \gamma)\,J_n(x) - G_n(x)$$

and verified by the method of differences.

The interpolation formulæ for other values of the argument are

$$Y_0(x \pm h) = \left[1 - \frac{h^2}{2} \pm \frac{h^3}{6x}\ \dots\right] Y_0(x) + \left[\mp h + \frac{h^2}{2x}\dots\right] Y_1(x)$$

$$Y_1(x \pm h) = \left[1 \mp \frac{h}{x} - \frac{h^2}{2}\left(1 - \frac{2}{x^2}\right)\dots\right] Y_1(x) + \left[\pm h - \frac{h^2}{2x}\dots\right] Y_0(x).$$

Tables of the Neumann Cylinder Functions.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
0·02	−3·911532	−50·044118	0·76	−0·099484	−1·569515
0·04	−3·217189	−25·074360	0·78	−0·068482	−1·530927
0·06	−2·809980	−16·766014	0·80	−0·038237	−1·493705
0·08	−2·520090	−12·620908	0·82	−0·008725	−1·457735
0·10	−2·294335	−10·139907	0·84	+0·020080	−1·422912
0·12	−2·109042	−8·490185	0·86	+0·048199	−1·389144
0·14	−1·951600	−7·314934	0·88	+0·075652	−1·356346
0·16	−1·814487	−6·435818	0·90	+0·102458	−1·324442
0·18	−1·692861	−5·753809	0·92	+0·128635	−1·293362
0·20	−1·583421	−5·209517	0·94	+0·154198	−1·263043
0·22	−1·483817	−4·765173	0·96	+0·179162	−1·233429
0·24	−1·392318	−4·395614	0·98	+0·203539	−1·204467
0·26	−1·307611	−4·083430	1·00	+0·227344	−1·176110
0·28	−1·228681	−3·816195	1·02	+0·250588	−1·148315
0·30	−1·154725	−3·584806	1·04	+0·273280	−1·121042
0·32	−1·085096	−3·382440	1·06	+0·295433	−1·094256
0·34	−1·019269	−3·203886	1·08	+0·317054	−1·067922
0·36	−0·956809	−3·045093	1·10	+0·338152	−1·042011
0·38	−0·897355	−2·902869	1·12	+0·358737	−1·016496
0·40	−0·840601	−2·774662	1·14	+0·378815	−0·991350
0·42	−0·786288	−2·658408	1·16	+0·398393	−0·966551
0·44	−0·734196	−2·552423	1·18	+0·417479	−0·942079
0·46	−0·684132	−2·455317	1·20	+0·436078	−0·917912
0·48	−0·635932	−2·365931	1·22	+0·454197	−0·894033
0·50	−0·589450	−2·283297	1·24	+0·471841	−0·870426
0·52	−0·544561	−2·206594	1·26	+0·489016	−0·847076
0·54	−0·501152	−2·135127	1·28	+0·505726	−0·823970
0·56	−0·459125	−2·068299	1·30	+0·521976	−0·801094
0·58	−0·418392	−2·005598	1·32	+0·537771	−0·778438
0·60	−0·378875	−1·946580	1·34	+0·553115	−0·755991
0·62	−0·340507	−1·890861	1·36	+0·568012	−0·733743
0·64	−0·303222	−1·838105	1·38	+0·582466	−0·711687
0·66	−0·266965	−1·788017	1·40	+0·596481	−0·689814
0·68	−0·231685	−1·740338	1·42	+0·610060	−0·668116
0·70	−0·197337	−1·694840	1·44	+0·623207	−0·646589
0·72	−0·163878	−1·651320	1·46	+0·635925	−0·625226
0·74	−0·131272	−1·609599	1·48	+0·648217	−0·604021

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
1·50	+0·660086	−0·582971	2·68	+0·714906	+0·397539
1·52	+0·671537	−0·562070	2·70	+0·706843	+0·408760
1·54	+0·682570	−0·541317	2·72	+0·698557	+0·419757
1·56	+0·693190	−0·520706	2·74	+0·690054	+0·430529
1·58	+0·703399	−0·500237	2·76	+0·681338	+0·441073
1·60	+0·713200	−0·479905	2·78	+0·672413	+0·451389
1·62	+0·722596	−0·459710	2·80	+0·663284	+0·461474
1·64	+0·731590	−0·439650	2·82	+0·653955	+0·471327
1·66	+0·740183	−0·419723	2·84	+0·644432	+0·480947
1·68	+0·748380	−0·399929	2·86	+0·634719	+0·490331
1·70	+0·756181	−0·380266	2·88	+0·624821	+0·499477
1·72	+0·763591	−0·360734	2·90	+0·614742	+0·508385
1·74	+0·770612	−0·341333	2·92	+0·604487	+0·517054
1·76	+0·777245	−0·322063	2·94	+0·594061	+0·525482
1·78	+0·783495	−0·302924	2·96	+0·583469	+0·533667
1·80	+0·789363	−0·283916	2·98	+0·572716	+0·541608
1·82	+0·794853	−0·265040	3·00	+0·561806	+0·549305
1·84	+0·799966	−0·246297	3·02	+0·550745	+0·556756
1·86	+0·804705	−0·227687	3·04	+0·539538	+0·563960
1·88	+0·809074	−0·209212	3·06	+0·528189	+0·570917
1·90	+0·813075	−0·190874	3·08	+0·516703	+0·577625
1·92	+0·816710	−0·172672	3·10	+0·505085	+0·584083
1·94	+0·819982	−0·154608	3·12	+0·493341	+0·590291
1·96	+0·822895	−0·136685	3·14	+0·481475	+0·596249
1·98	+0·825451	−0·118904	3·16	+0·469493	+0·601955
2·00	+0·827652	−0·101266	3·18	+0·457399	+0·607408
2·02	+0·829502	−0·083773	3·20	+0·445198	+0·612620
2·04	+0·831004	−0·066427	3·22	+0·432896	+0·617559
2·06	+0·832161	−0·049231	3·24	+0·420498	+0·622254
2·08	+0·832974	−0·032186	3·26	+0·408008	+0·626696
2·10	+0·833449	−0·015294	3·28	+0·395431	+0·630885
2·12	+0·833587	+0·001443	3·30	+0·382774	+0·634820
2·14	+0·833392	+0·018022	3·32	+0·370040	+0·638501
2·16	+0·832867	+0·034441	3·34	+0·357236	+0·641929
2·18	+0·832016	+0·050698	3·36	+0·344365	+0·645103
2·20	+0·830841	+0·066791	3·38	+0·331433	+0·648024
2·22	+0·829345	+0·082717	3·40	+0·318446	+0·650691
2·24	+0·827533	+0·098473	3·42	+0·305407	+0·653106
2·26	+0·825407	+0·114058	3·44	+0·292323	+0·655269
2·28	+0·822972	+0·129470	3·46	+0·279198	+0·657180
2·30	+0·820230	+0·144705	3·48	+0·266038	+0·658840
2·32	+0·817185	+0·159762	3·50	+0·252846	+0·660249
2·34	+0·813841	+0·174637	3·52	+0·239629	+0·661408
2·36	+0·810201	+0·189329	3·54	+0·226392	+0·662318
2·38	+0·806269	+0·203836	3·56	+0·213138	+0·662980
2·40	+0·802048	+0·218154	3·58	+0·199874	+0·663395
2·42	+0·797544	+0·232281	3·60	+0·186604	+0·663564
2·44	+0·792758	+0·246215	3·62	+0·173333	+0·663487
2·46	+0·787696	+0·259954	3·64	+0·160066	+0·663166
2·48	+0·782362	+0·273495	3·66	+0·146808	+0·662602
2·50	+0·776758	+0·286837	3·68	+0·133564	+0·661797
2·52	+0·770889	+0·299976	3·70	+0·120338	+0·660752
2·54	+0·764760	+0·312910	3·72	+0·107135	+0·659468
2·56	+0·758374	+0·325637	3·74	+0·093961	+0·657947
2·58	+0·751736	+0·338156	3·76	+0·080819	+0·656190
2·60	+0·744850	+0·350464	3·78	+0·067715	+0·654199
2·62	+0·737719	+0·362558	3·80	+0·054653	+0·651976
2·64	+0·730349	+0·374436	3·82	+0·041637	+0·649523
2·66	+0·722743	+0·386097	3·84	+0·028673	+0·646841

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
3·86	+0·015765	+0·643933	5·04	−0·512543	+0·172467
3·88	+0·002917	+0·640800	5·06	−0·515883	+0·161521
3·90	−0·009866	+0·637444	5·08	−0·519004	+0·150556
3·92	−0·022579	+0·633868	5·10	−0·521905	+0·139577
3·94	−0·035219	+0·630073	5·12	−0·524587	+0·128587
3·96	−0·047781	+0·626063	5·14	−0·527048	+0·117590
3·98	−0·060260	+0·621839	5·16	−0·529290	+0·106591
4·00	−0·072653	+0·617404	5·18	−0·531312	+0·095594
4·02	−0·084955	+0·612760	5·20	−0·533114	+0·084602
4·04	−0·097162	+0·607909	5·22	−0·534696	+0·073619
4·06	−0·109270	+0·602855	5·24	−0·536059	+0·062650
4·08	−0·121275	+0·597600	5·26	−0·537202	+0·051700
4·10	−0·133172	+0·592146	5·28	−0·538127	+0·040771
4·12	−0·144959	+0·586497	5·30	−0·538833	+0·029867
4·14	−0·156631	+0·580655	5·32	−0·539322	+0·018994
4·16	−0·168184	+0·574623	5·34	−0·539593	+0·008154
4·18	−0·179615	+0·568403	5·36	−0·539648	−0·002650
4·20	−0·190919	+0·562000	5·38	−0·539488	−0·013412
4·22	−0·202093	+0·555415	5·40	−0·539112	−0·024128
4·24	−0·213134	+0·548652	5·42	−0·538523	−0·034796
4·26	−0·224038	+0·541715	5·44	−0·537721	−0·045411
4·28	−0·234802	+0·534605	5·46	−0·536707	−0·055970
4·30	−0·245422	+0·527327	5·48	−0·535482	−0·066468
4·32	−0·255894	+0·519884	5·50	−0·534048	−0·076903
4·34	−0·266216	+0·512279	5·52	−0·532406	−0·087270
4·36	−0·276384	+0·504515	5·54	−0·530558	−0·097566
4·38	−0·286395	+0·496596	5·56	−0·528504	−0·107786
4·40	−0·296247	+0·488525	5·58	−0·526247	−0·117929
4·42	−0·305936	+0·480306	5·60	−0·523788	−0·127990
4·44	−0·315458	+0·471943	5·62	−0·521128	−0·137965
4·46	−0·324812	+0·463438	5·64	−0·518270	−0·147852
4·48	−0·333995	+0·454795	5·66	−0·515215	−0·157646
4·50	−0·343003	+0·446018	5·68	−0·511964	−0·167345
4·52	−0·351834	+0·437112	5·70	−0·508521	−0·176945
4·54	−0·360487	+0·428078	5·72	−0·504887	−0·186443
4·56	−0·368957	+0·418921	5·74	−0·501064	−0·195836
4·58	−0·377243	+0·409646	5·76	−0·497055	−0·205120
4·60	−0·385342	+0·400255	5·78	−0·492861	−0·214293
4·62	−0·393252	+0·390753	5·80	−0·488484	−0·223350
4·64	−0·400971	+0·381144	5·82	−0·483927	−0·232290
4·66	−0·408497	+0·371430	5·84	−0·479194	−0·241110
4·68	−0·415828	+0·361617	5·86	−0·474284	−0·249806
4·70	−0·422961	+0·351708	5·88	−0·469202	−0·258375
4·72	−0·429895	+0·341706	5·90	−0·463949	−0·266815
4·74	−0·436629	+0·331617	5·92	−0·458529	−0·275123
4·76	−0·443160	+0·321444	5·94	−0·452945	−0·283297
4·78	−0·449486	+0·311191	5·96	−0·447199	−0·291333
4·80	−0·455607	+0·300862	5·98	−0·441293	−0·299229
4·82	−0·461520	+0·290461	6·00	−0·435231	−0·306982
4·84	−0·467225	+0·279992	6·02	−0·429015	−0·314590
4·86	−0·472719	+0·269459	6·04	−0·422648	−0·322051
4·88	−0·478003	+0·258867	6·06	−0·416134	−0·329363
4·90	−0·483074	+0·248219	6·08	−0·409474	−0·336522
4·92	−0·487931	+0·237519	6·10	−0·402674	−0·343527
4·94	−0·492574	+0·226772	6·12	−0·395735	−0·350376
4·96	−0·497002	+0·215981	6·14	−0·388660	−0·357066
4·98	−0·501213	+0·205151	6·16	−0·381453	−0·363595
5·00	−0·505208	+0·194286	6·18	−0·374117	−0·369961
5·02	−0·508984	+0·183390	6·20	−0·366656	−0·376164

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
6·22	−0·359072	−0·382201	7·40	+0·174739	−0·416299
6·24	−0·351369	−0·388069	7·42	+0 183019	−0·411604
6·26	−0·343550	−0·393768	7·44	+0·191203	−0·406760
6·28	−0·335619	−0·399295	7·46	+0·199288	−0·401770
6·30	−0·327579	−0·404649	7·48	+0·207272	−0·396635
6·32	−0·319434	−0·409828	7·50	+0·215153	−0·391359
6·34	−0·311187	−0·414832	7·52	+0·222926	−0·385943
6·36	−0·302842	−0·419657	7·54	+0·230589	−0·380390
6·38	−0·294402	−0·424305	7·56	+0·238140	−0·374702
6·40	−0·285871	−0·428773	7·58	+0·245577	−0·368882
6·42	−0·277253	−0·433060	7·60	+0·252895	−0·362933
6·44	−0·268550	−0·437165	7·62	+0·260093	−0·356857
6·46	−0·259767	−0·441086	7·64	+0·267168	−0·350657
6·48	−0·250908	−0·444824	7·66	+0·274118	−0·344335
6·50	−0·241976	−0·448377	7·68	+0·280941	−0·337895
6·52	−0·232974	−0·451743	7·70	+0·287633	−0·331339
6·54	−0·223907	−0·454924	7·72	+0·294193	−0·324670
6·56	−0·214778	−0·457917	7·74	+0·300619	−0·317890
6·58	−0·205592	−0·460723	7·76	+0·306909	−0·311003
6·60	−0·196351	−0·463340	7·78	+0·313059	−0·304012
6·62	−0·187059	−0·465768	7·80	+0·319068	−0·296919
6·64	−0·177721	−0·468008	7·82	+0·324935	−0·289727
6·66	−0·168340	−0·470058	7·84	+0·330657	−0·282440
6·68	−0·158920	−0·471918	7·86	+0·336232	−0·275061
6·70	−0·149465	−0·473589	7·88	+0·341659	−0·267593
6·72	−0·139978	−0·475069	7·90	+0·346935	−0·260038
6·74	−0·130463	−0·476360	7·92	+0·352060	−0·252399
6·76	−0·120925	−0·477461	7·94	+0·357031	−0·244681
6·78	−0·111366	−0·478372	7·96	+0·361846	−0·236886
6·80	−0·101791	−0·479093	7·98	+0·366505	−0·229018
6·82	−0·092203	−0·479626	8·00	+0·371007	−0·221079
6·84	−0·082607	−0·479969	8·02	+0·375348	−0·213073
6·86	−0·073006	−0·480123	8·04	+0·379529	−0·205003
6·88	−0·063403	−0·480090	8·06	+0·383548	−0·196873
6·90	−0·053804	−0·479868	8·08	+0·387404	−0·188686
6·92	−0·044211	−0·479460	8·10	+0·391095	−0·180445
6·94	−0·034627	−0·478865	8·12	+0·394621	−0·172152
6·96	−0·025057	−0·478085	8·14	+0·397981	−0·163812
6·98	−0·015504	−0·477120	8·16	+0·401173	−0·155429
7·00	−0·005973	−0·475972	8·18	+0·404198	−0·147005
7·02	+0·003533	−0·474640	8·20	+0·407053	−0·138543
7·04	+0·013011	−0·473126	8·22	+0·409739	−0·130048
7·06	+0·022457	−0·471431	8·24	+0·412255	−0·121522
7·08	+0·031867	−0·469557	8·26	+0·414600	−0·112969
7·10	+0·041238	−0·467504	8·28	+0·416773	−0·104392
7·12	+0·050566	−0·465274	8·30	+0·418775	−0·095795
7·14	+0·059848	−0·462868	8·32	+0·420605	−0·087181
7·16	+0·069080	−0·460288	8·34	+0·422262	−0·078553
7·18	+0·078258	−0·457534	8·36	+0·423747	−0·069914
7·20	+0·087380	−0·454609	8·38	+0·425059	−0·061269
7·22	+0·096442	−0·451514	8·40	+0·426198	−0·052621
7·24	+0·105440	−0·448250	8·42	+0·427164	−0·043972
7·26	+0·114371	−0·444820	8·44	+0·427957	−0·035326
7·28	+0·123231	−0·441225	8·46	+0·428577	−0·026687
7·30	+0·132018	−0·437467	8·48	+0·429024	−0·018058
7·32	+0·140729	−0·433548	8·50	+0·429299	−0·009442
7·34	+0·149359	−0·429470	8·52	+0·429402	−0·000843
7·36	+0·157907	−0·425234	8·54	+0·429333	+0·007737
7·38	+0·166368	−0·420843	8·56	+0·429093	+0·016293

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
8·58	+0·428682	+0·024823	9·76	+0·152558	+0·380212
8·60	+0·428100	+0·033324	9·78	+0·144931	+0·382406
8·62	+0·427349	+0·041792	9·80	+0·137263	+0·384445
8·64	+0·426428	+0·050223	9·82	+0·129555	+0·386327
8·66	+0·425340	+0·058615	9·84	+0·121811	+0·388053
8·68	+0·424084	+0·066964	9·86	+0·114034	+0·389622
8·70	+0·422662	+0·075268	9·88	+0·106227	+0·391034
8·72	+0·421074	+0·083524	9·90	+0·098393	+0·392288
8·74	+0·419321	+0·091728	9·92	+0·090536	+0·393385
8·76	+0·417405	+0·099876	9·94	+0·082659	+0·394323
8·78	+0·415327	+0·107966	9·96	+0·074764	+0·395104
8·80	+0·413087	+0·115996	9·98	+0·066856	+0·395727
8·82	+0·410687	+0·123962	10·00	+0·058936	+0·396193
8·84	+0·408129	+0·131860	10·02	+0·051009	+0·396500
8·86	+0·405413	+0·139689	10·04	+0·043077	+0·396650
8·88	+0·402542	+0·147445	10·06	+0·035144	+0·396643
8·90	+0·399516	+0·155126	10·08	+0·027213	+0·396479
8·92	+0·396338	+0·162728	10·10	+0·019286	+0·396158
8·94	+0·393008	+0·170249	10·12	+0·011367	+0·395681
8·96	+0·389528	+0·177686	10·14	+0·003460	+0·395049
8·98	+0·385901	+0·185036	10·16	−0·004434	+0·394262
9·00	+0·382127	+0·192297	10·18	−0·012310	+0·393320
9·02	+0·378209	+0·199465	10·20	−0·020165	+0·392224
9·04	+0·374149	+0·206539	10·22	−0·027998	+0·390975
9·06	+0·369948	+0·213517	10·24	−0·035804	+0·389574
9·08	+0·365609	+0·220394	10·26	−0·043580	+0·388021
9·10	+0·361133	+0·227169	10·28	−0·051323	+0·386318
9·12	+0·356523	+0·233840	10·30	−0·059031	+0·384466
9·14	+0·351781	+0·240404	10·32	−0·066701	+0·382464
9·16	+0·346908	+0·246858	10·34	−0·074329	+0·380316
9·18	+0·341907	+0·253201	10·36	−0·081912	+0·378020
9·20	+0·336780	+0·259430	10·38	−0·089449	+0·375580
9·22	+0·331530	+0·265544	10·40	−0·096935	+0·372996
9·24	+0·326159	+0·271539	10·42	−0·104367	+0·370269
9·26	+0·320670	+0·277414	10·44	−0·111744	+0·367400
9·28	+0·315064	+0·283167	10·46	−0·119063	+0·364392
9·30	+0·309344	+0·288795	10·48	−0·126319	+0·361245
9·32	+0·303513	+0·294297	10·50	−0·133511	+0·357961
9·34	+0·297573	+0·299672	10·52	−0·140637	+0·354541
9·36	+0·291527	+0·304917	10·54	−0·147692	+0·350987
9·38	+0·285377	+0·310030	10·56	−0·154675	+0·347302
9·40	+0·279126	+0·315009	10·58	−0·161583	+0·343486
9·42	+0·272778	+0·319853	10·60	−0·168414	+0·339541
9·44	+0·266334	+0·324561	10·62	−0·175164	+0·335469
9·46	+0·259796	+0·329131	10·64	−0·181832	+0·331271
9·48	+0·253169	+0·333561	10·66	−0·188414	+0·326950
9·50	+0·246455	+0·337850	10·68	−0·194909	+0·322508
9·52	+0·239656	+0·341996	10·70	−0·201314	+0·317947
9·54	+0·232776	+0·345999	10·72	−0·207626	+0·313268
9·56	+0·225817	+0·349856	10·74	−0·213844	+0·308474
9·58	+0·218783	+0·353567	10·76	−0·219964	+0·303566
9·60	+0·211675	+0·357131	10·78	−0·225985	+0·298547
9·62	+0·204498	+0·360546	10·80	−0·231905	+0·293419
9·64	+0·197254	+0·363811	10·82	−0·237722	+0·288185
9·66	+0·189947	+0·366926	10·84	−0·243433	+0·282846
9·68	+0·182578	+0·369890	10·86	−0·249035	+0·277405
9·70	+0·175152	+0·372701	10·88	−0·254528	+0·271864
9·72	+0·167671	+0·375359	10·90	−0·259909	+0·266225
9·74	+0·160139	+0·377862	10·92	−0·265176	+0·260491

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
10·94	−0·270328	+0·254665	12·12	−0·332007	−0·155112
10·96	−0·275362	+0·248748	12·14	−0·328841	−0·161460
10·98	−0·280277	+0·242743	12·16	−0·325550	−0·167733
11·00	−0·285071	+0·236653	12·18	−0·322133	−0·173929
11·02	−0·289743	+0·230480	12·20	−0·318593	−0·180046
11·04	−0·294290	+0·224228	12·22	−0·314932	−0·186082
11·06	−0·298711	+0·217898	12·24	−0·311150	−0·192034
11·08	−0·303005	+0·211492	12·26	−0·307251	−0·197899
11·10	−0·307170	+0·205014	12·28	−0·303235	−0·203676
11·12	−0·311205	+0·198467	12·30	−0·299104	−0·209364
11·14	−0·315109	+0·191853	12·32	−0·294861	−0·214959
11·16	−0·318879	+0·185175	12·34	−0·290507	−0·220460
11·18	−0·322515	+0·178435	12·36	−0·286043	−0·225864
11·20	−0·326016	+0·171637	12·38	−0·281473	−0·231170
11·22	−0·329380	+0·164783	12·40	−0·276797	−0·236376
11·24	−0·332607	+0·157875	12·42	−0·272018	−0·241479
11·26	−0·335695	+0·150917	12·44	−0·267139	−0·246478
11·28	−0·338643	+0·143912	12·46	−0·262160	−0·251372
11·30	−0·341451	+0·136862	12·48	−0·257084	−0·256158
11·32	−0·344118	+0·129771	12·50	−0·251914	−0·260834
11·34	−0·346642	+0·122640	12·52	−0·246652	−0·265399
11·36	−0·349023	+0·115473	12·54	−0·241299	−0·269851
11·38	−0·351261	+0·108274	12·56	−0·235859	−0·274189
11·40	−0·353354	+0·101044	12·58	−0·230333	−0·278412
11·42	−0·355302	+0·093786	12·60	−0·224723	−0·282517
11·44	−0·357105	+0·086504	12·62	−0·219032	−0·286503
11·46	−0·358762	+0·079200	12·64	−0·213263	−0·290369
11·48	−0·360273	+0·071878	12·66	−0·207418	−0·294114
11·50	−0·361637	+0·064540	12·68	−0·201500	−0·297737
11·52	−0·362854	+0·057189	12·70	−0·195510	−0·301235
11·54	−0·363924	+0·049828	12·72	−0·189451	−0·304608
11·56	−0·364847	+0·042460	12·74	−0·183326	−0·307855
11·58	−0·365623	+0·035088	12·76	−0·177138	−0·310974
11·60	−0·366251	+0·027715	12·78	−0·170888	−0·313965
11·62	−0·366731	+0·020344	12·80	−0·164580	−0·316827
11·64	−0·367065	+0·012977	12·82	−0·158216	−0·319558
11·66	−0·367251	+0·005617	12·84	−0·151799	−0·322158
11·68	−0·367289	−0·001732	12·86	−0·145331	−0·324626
11·70	−0·367181	−0·009068	12·88	−0·138815	−0·326961
11·72	−0·366927	−0·016387	12·90	−0·132253	−0·329163
11·74	−0·366526	−0·023688	12·92	−0·125649	−0·331231
11·76	−0·365979	−0·030967	12·94	−0·119005	−0·333163
11·78	−0·365288	−0·038221	12·96	−0·112323	−0·334960
11·80	−0·364451	−0·045447	12·98	−0·105607	−0·336622
11·82	−0·363470	−0·052643	13·00	−0·098859	−0·338147
11·84	−0·362345	−0·059807	13·02	−0·092082	−0·339536
11·86	−0·361078	−0·066935	13·04	−0·085279	−0·340787
11·88	−0·359668	−0·074024	13·06	−0·078452	−0·341901
11·90	−0·358117	−0·081071	13·08	−0·071604	−0·342878
11·92	−0·356426	−0·088075	13·10	−0·064738	−0·343717
11·94	−0·354595	−0·095032	13·12	−0·057856	−0·344418
11·96	−0·352625	−0·101939	13·14	−0·050962	−0·344981
11·98	−0·350517	−0·108795	13·16	−0·044058	−0·345406
12·00	−0·348273	−0·115596	13·18	−0·037147	−0·345694
12·02	−0·345894	−0·122340	13·20	−0·030231	−0·345843
12·04	−0·343380	−0·129024	13·22	−0·023314	−0·345855
12·06	−0·340733	−0·135645	13·24	−0·016398	−0·345729
12·08	−0·337955	−0·142202	13·26	−0·009485	−0·345466
12·10	−0·335046	−0·148692	13·28	−0·002580	−0·345067

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
13·30	+0·004316	−0·344531	14·42	+0·299680	−0·129889
13·32	+0·011201	−0·343858	14·44	+0·302216	−0·123694
13·34	+0·018070	−0·343050	14·46	+0·304628	−0·117459
13·36	+0·024922	−0·342107	14·48	+0·306914	−0·111185
13·38	+0·031753	−0·341029	14·50	+0·309075	−0·104876
13·40	+0·038562	−0·339817	14·52	+0·311109	−0·098534
13·42	+0·045345	−0·338472	14·54	+0·313016	−0·092161
13·44	+0·052100	−0·336994	14·56	+0·314795	−0·085760
13·46	+0·058824	−0·335386	14·58	+0·316446	−0·079334
13·48	+0·065515	−0·333645	14·60	+0·317968	−0·072886
13·50	+0·072169	−0·331775	14·62	+0·319362	−0·066417
13·52	+0·078785	−0·329776	14·64	+0·320625	−0·059931
13·54	+0·085359	−0·327649	14·66	+0·321759	−0·053429
13·56	+0·091890	−0·325395	14·68	+0·322762	−0·046915
13·58	+0·098374	−0·323014	14·70	+0·323635	−0·040392
13·60	+0·104809	−0·320508	14·72	+0·324378	−0·033861
13·62	+0·111193	−0·317879	14·74	+0·324990	−0·027326
13·64	+0·117524	−0·315127	14·76	+0·325471	−0·020788
13·66	+0·123798	−0·312254	14·78	+0·325821	−0·014251
13·68	+0·130013	−0·309261	14·80	+0·326041	−0·007717
13·70	+0·136167	−0·306150	14·82	+0·326130	−0·001189
13·72	+0·142258	−0·302922	14·84	+0·326088	+0·005330
13·74	+0·148283	−0·299577	14·86	+0·325917	+0·011839
13·76	+0·154241	−0·296118	14·88	+0·325615	+0·018334
13·78	+0·160128	−0·292547	14·90	+0·325183	+0·024813
13·80	+0·165942	−0·288865	14·92	+0·324622	+0·031274
13·82	+0·171681	−0·285073	14·94	+0·323932	+0·037714
13·84	+0·177344	−0·281173	14·96	+0·323114	+0·044130
13·86	+0·182928	−0·277167	14·98	+0·322167	+0·050519
13·88	+0·188430	−0·273056	15·00	+0·321093	+0·056880
13·90	+0·193849	−0·268843	15·02	+0·319893	+0·063210
13·92	+0·199183	−0·264529	15·04	+0·318566	+0·069507
13·94	+0·204430	−0·260116	15·06	+0·317113	+0·075767
13·96	+0·209587	−0·255606	15·08	+0·315535	+0·081989
13·98	+0·214653	−0·251001	15·10	+0·313833	+0·088171
14·00	+0·219627	−0·246303	15·12	+0·312008	+0·094309
14·02	+0·224505	−0·241513	15·14	+0·310061	+0·100401
14·04	+0·229286	−0·236634	15·16	+0·307993	+0·106445
14·06	+0·233969	−0·231668	15·18	+0·305804	+0·112439
14·08	+0·238553	−0·226617	15·20	+0·303496	+0·118380
14·10	+0·243034	−0·221483	15·22	+0·301069	+0·124266
14·12	+0·247411	−0·216268	15·24	+0·298525	+0·130095
14·14	+0·251684	−0·210975	15·26	+0·295865	+0·135865
14·16	+0·255850	−0·205605	15·28	+0·293091	+0·141573
14·18	+0·259908	−0·200161	15·30	+0·290203	+0·147217
14·20	+0·263856	−0·194645	15·32	+0·287203	+0·152796
14·22	+0·267693	−0·189059	15·34	+0·284092	+0·158306
14·24	+0·271418	−0·183406	15·36	+0·280871	+0·163746
14·26	+0·275029	−0·177688	15·38	+0·277542	+0·169113
14·28	+0·278525	−0·171907	15·40	+0·274107	+0·174406
14·30	+0·281905	−0·166066	15·42	+0·270567	+0·179624
14·32	+0·285167	−0·160167	15·44	+0·266923	+0·184763
14·34	+0·288311	−0·154213	15·46	+0·263177	+0·189822
14·36	+0·291335	−0·148205	15·48	+0·259330	+0·194799
14·38	+0·294239	−0·142147	15·50	+0·255385	+0·199691
14·40	+0·297021	−0·136041			

The Neumann G Functions.

The Neumann Functions $G_n(x)$ of order greater than unity are of frequent occurrence in physical problems, such as the diffraction of light, pressure of radiation, &c. Tables of the functions have been found from those of $G_0(x)$ and $G_1(x)$ by (*a*) direct calculation and (*b*) logarithmic computation from the recurrence formula

$$G_{n+1}(x) = \frac{2n}{x} G_n(x) - G_{n-1}(x)$$

and verified in the case when x is an integer by the relation

$$J_n(x)\, G_{n+1}(x) - J_{n+1}(x)\, G_n(x) = \frac{1}{x}.$$

The Bessel Functions $J_n(x)$ for positive integral values of n and x have been given by Meissel for $x = 1$ to $x = 24$.

The Tables may be used to calculate $G_n(x)$ for other values of the argument x by employing the following formula:

$$G_n(x+h) = G_n(x) + h\left[\frac{n}{x} G_n(x) - G_{n+1}(x)\right] + \frac{h^2}{2!}\left[\left\{\frac{n(n-1)}{x^2} - 1\right\} G_n(x) + \frac{1}{x} G_{n+1}(x)\right] + \ldots$$

Tables of the Neumann Functions. $G_n(x)$.

$G_n(x)$	$x =$ 0·1	0·2	0·3	0·4	0·5
$n = 0$	+ 2·40998	+1·69820	+1·26806	+0·95194	+0·69825
1	+10·14570	+5·22105	+3·60200	+2·79739	+2·31138
2	—	—	—	—	+8·54729

$G_n(x)$	$x =$ 0·6	0·7	0·8	0·9	1·0
$n = 0$	+0·48461	+0·29950	+0·13635	−0·00884	−0·13863
1	+1·97982	+1·73298	+1·53647	+1·37150	+1·22713
2	+6·11479	+4·65188	+3·70481	+3·05663	+2·59289
3	—	—	—	—	+9·14442

$G_n(x)$	$x =$ 1·1	1·2	1·3	1·4	1·5
$n = 0$	−0·25473	−0·35827	−0·45009	−0·53076	−0·60075
1	+1·09660	+0·97568	+0·86161	+0·75264	+0·64765
2	+2·24855	+1·98440	+1·77565	+1·60597	+1·46429
3	+7·07994	+5·63900	+4·60192	+3·83584	+3·25711

$G_n(x)$	$x =$ 1·6	1·7	1·8	1·9	2·0
$n = 0$	−0·66041	−0·71004	−0·74995	−0·78040	−0·80170
1	+0·54597	+0·44725	+0·35133	+0·25825	+0·16813
2	+1·34287	+1·23622	+1·14032	+1·05224	+0·96982
3	+2·81121	+2·46149	+2·18271	+1·95700	+1·77152
4	+9·19916	+7·45141	+6·13537	+5·12776	+4·34473

Tables of the Neumann Functions. $G_n(x)$—continued.

$G_n(x)$	$x=$ 2·1	2·2	2·3	2·4	2·5
$n=0$	−0·81413	−0·81805	−0·81379	−0·80176	−0·78237
1	+0·08118	−0·00234	−0·08212	−0·15785	−0·22921
2	+0·89144	+0·81592	+0·74238	+0·67022	+0·59900
3	+1·61681	+1·48583	+1·37322	+1·27488	+1·18761
4	+3·72802	+3·23634	+2·83993	+2·51698	+2·25126
5	—	—	+8·50480	+7·11504	+6·01643

$G_n(x)$	$x=$ 2·6	2·7	2·8	2·9	3·0
$n=0$	−0·75607	−0·72336	−0·68474	−0·64075	−0·59195
1	−0·29588	−0·35756	−0·41398	−0·46486	−0·51000
2	+0·52847	+0·45849	+0·38904	+0·32015	+0·25196
3	+1·10891	+1·03682	+0·96974	+0·90645	+0·84594
4	+2·03056	+1·84554	+1·68899	+1·55526	+1·43992
5	+5·13897	+4·43145	+3·85593	+3·38393	+2·99385
6	—	—	—	—	+8·53959

$G_n(x)$	$x=$ 3·1	3·2	3·3	3·4	3·5
$n=0$	−0·53894	−0·48232	−0·42269	−0·36068	−0·29692
1	−0·54920	−0·58231	−0·60924	−0·62991	−0·64432
2	+0·18462	+0·11837	+0·05345	−0·00986	−0·07127
3	+0·78742	+0·73028	+0·67403	+0·61832	+0·56287
4	+1·33942	+1·25090	+1·17206	+1·10100	+1·03619
5	+2·66914	+2·39697	+2·16732	+1·97228	+1·80557
6	+7·27071	+6·23963	+5·39557	+4·69982	+4·12257

$G_n(x)$	$x=$ 3·6	3·7	3·8	3·9	4·0
$n=0$	−0·23202	−0·16662	−0·10132	−0·03672	+0·02661
1	−0·65250	−0·65451	−0·65049	−0·64060	−0·62506
2	−0·13048	−0·18717	−0·24104	−0·29180	−0·33914
3	+0·50752	+0·45217	+0·39676	+0·34133	+0·28592
4	+0·97635	+0·92041	+0·86751	+0·81691	+0·76802
5	+1·66214	+1·53791	+1·42957	+1·33439	+1·25012
6	+3·64070	+3·23611	+2·89452	+2·60460	+2·35728
7	—	+8·95757	+7·71102	+6·67976	+5·82172

$G_n(x)$	$x=$ 4·1	4·2	4·3	4·4	4·5
$n=0$	+0·08811	+0·14726	+0·20357	+0·25657	+0·30584
1	−0·60412	−0·57807	−0·54726	−0·51203	−0·47281
2	−0·38281	−0·42254	−0·45811	−0·48931	−0·51598
3	+0·23065	+0·17566	+0·12111	+0·06721	+0·01416
4	+0·72034	+0·67348	+0·62710	+0·58095	+0·53486
5	+1·17490	+1·10715	+1·04558	+0·98908	+0·93670
6	+2·14526	+1·96260	+1·80449	+1·66694	+1·54669
7	+5·10391	+4·50029	+3·99020	+3·55714	+3·18781
8	—	—	—	+9·65122	+8·37095

Tables of the Neumann Functions. $G_n(x)$—continued.

$G_n(x)$	$x =$ 4·6	4·7	4·8	4·9	5·0
$n = 0$	+0·35101	+0·39174	+0·42773	+0·45876	+0·48462
1	−0·43000	−0·38406	−0·33547	−0·28470	−0·23226
2	−0·53797	−0·55517	−0·56751	−0·57496	−0·57752
3	−0·03780	−0·08842	−0·13746	−0·18466	−0·22976
4	+0·48866	+0·44229	+0·39569	+0·34885	+0·30182
5	+0·88765	+0·84125	+0·79694	+0·75421	+0·71266
6	+1·44101	+1·34761	+1·26460	+1·19036	+1·12351
7	+2·87150	+2·59946	+2·36457	+2·16095	+1·98376
8	+7·29834	+6·39546	+5·63205	+4·98377	+4·43101

$G_n(x)$	$x =$ 5·1	5·2	5·3	5·4	5·5
$n = 0$	+0·50517	+0·52033	+0·53005	+0·53433	+0·53325
1	−0·17866	−0·12439	−0·06998	−0·01591	+0·03732
2	−0·57523	−0·56817	−0·55645	−0·54023	−0·51968
3	−0·27251	−0·31266	−0·34999	−0·38426	−0·41527
4	+0·25464	+0·20741	+0·16024	+0·11327	+0·06666
5	+0·67194	+0·63175	+0·59186	+0·55207	+0·51223
6	+1·06289	+1·00750	+0·95647	+0·90908	+0·86467
7	+1·82897	+1·69324	+1·57374	+1·46811	+1·37432
8	+3·95783	+3·55123	+3·20058	+2·89712	+2·63361
9	—	+9·23362	+8·08839	+7·11596	+6·28707

$G_n(x)$	$x =$ 5·6	5·7	5·8	5·9	6·0
$n = 0$	+0·52691	+0·51547	+0·49911	+0·47810	+0·45270
1	+0·08923	+0·13937	+0·18729	+0·23260	+0·27491
2	−0·49505	−0·46657	−0·43453	−0·39925	−0·36106
3	−0·44283	−0·46678	−0·48697	−0·50328	−0·51561
4	+0·02058	−0·02478	−0·06923	−0·11256	−0·15455
5	+0·47224	+0·43200	+0·39148	+0·35066	+0·30954
6	+0·82270	+0·78268	+0·74419	+0·70689	+0·67046
7	+1·29069	+1·21574	+1·14823	+1·08709	+1·03137
8	+2·40402	+2·20335	+2·02740	+1·87264	+1·73607
9	+5·57794	+4·96911	+4·44461	+3·99125	+3·59816
10	—	—	—	—	+9·05841

$G_n(x)$	$x =$ 6·5	7·0	7·5	8·0	8·5
$n = 0$	+0·27213	+0·04076	−0·18428	−0·35111	−0·42444
1	+0·43054	+0·47543	+0·40704	+0·24828	+0·04111
2	−0·13965	+0·09507	+0·29282	+0·41318	+0·43411
3	−0·51648	−0·42110	−0·25087	−0·04169	+0·16318
4	−0·33710	−0·45602	−0·49351	−0·44445	−0·31892
5	+0·10159	−0·10006	−0·27555	−0·40275	−0·46334
6	+0·49339	+0·31307	+0·12612	−0·05900	−0·22619
7	+0·80929	+0·63676	+0·47734	+0·31426	+0·14402
8	+1·24969	+0·96044	+0·76491	+0·60895	+0·46340
9	+2·26687	+1·55854	+1·15447	+0·90364	+0·72826
10	+5·02780	+3·04723	+2·00582	+1·42424	+1·07879
11	—	+7·14782	+4·19437	+2·65697	+1·81008
12	—	—	—	+5·88241	+3·60612
13	—	—	—	—	+8·37191

Tables of the Neumann Functions. $G_n(x)$—continued.

$G_n(x)$	$x=$ 9·0	9·5	10·0	10·5	11·0
$n=0$	−0·39260	−0·26894	−0·08745	+0·10608	+0·26522
1	−0·16386	−0·31915	−0·39115	−0·36710	−0·25715
2	+0·35619	+0·20175	+0·00922	−0·17600	−0·31198
3	+0·32216	+0·40410	+0·39484	+0·30005	+0·14370
4	−0·14141	+0·05347	+0·22769	+0·34746	+0·39036
5	−0·44786	−0·35907	−0·21269	−0·03532	+0·14020
6	−0·35621	−0·43144	−0·44038	−0·38110	−0·26291
7	−0·02709	−0·18591	−0·31576	−0·40022	−0·42701
8	+0·31408	+0·15747	−0·00169	−0·15253	−0·28056
9	+0·58544	+0·45112	+0·31306	+0·16780	+0·01893
10	+0·85681	+0·69729	+0·56519	+0·44018	+0·31153
11	+1·31859	+1·01685	+0·81733	+0·67064	+0·54749
12	+2·36640	+1·65753	+1·23293	+0·96497	+0·78344
13	+4·99180	+3·17058	+2·14171	+1·53501	+1·16185

$G_n(x)$	$x=$ 11·5	12·0	12·5	13·0	13·5
$n=0$	+0·35379	+0·35380	+0·26894	+0·12285	−0·04724
1	−0·09102	+0·08969	+0·24165	+0·33000	+0·33619
2	−0·36962	−0·33885	−0·23028	−0·07208	+0·09705
3	−0·03755	−0·20264	−0·31534	−0·35217	−0·30743
4	+0·35003	+0·23753	+0·07892	−0·09046	−0·23369
5	+0·28105	+0·36100	+0·36584	+0·29651	+0·16895
6	−0·10564	+0·06330	+0·21376	+0·31854	+0·35883
7	−0·39128	−0·29770	−0·16064	−0·00247	+0·15001
8	−0·37070	−0·41061	−0·39367	−0·32120	−0·20326
9	−0·12448	−0·24979	−0·34326	−0·39285	−0·39092
10	+0·17587	+0·03593	−0·10063	−0·22275	−0·31796
11	+0·43034	+0·30968	+0·18226	+0·05016	−0·08013
12	+0·64738	+0·53181	+0·42140	+0·30763	+0·18737
13	+0·92073	+0·75394	+0·62684	+0·51778	+0·41324

$G\ (x)$	$x=$ 14·0	14·5	15·0	15·5	16·0
$n=0$	−0·19979	−0·29893	−0·32274	−0·26805	−0·15050
1	+0·26177	+0·12730	−0·03310	−0·18031	−0·27956
2	+0·23719	+0·31648	+0·31833	+0·24478	+0·11555
3	−0·19400	−0·03999	+0·11799	+0·24348	+0·30845
4	−0·32033	−0·33303	−0·27113	−0·15053	+0·00012
5	+0·01095	−0·14375	−0·26259	−0·32117	−0·30839
6	+0·32815	+0·23390	+0·09607	−0·05667	−0·19286
7	+0·27032	+0·33732	+0·33945	+0·27730	+0·16375
8	−0·05783	+0·09179	+0·22075	+0·30713	+0·33614
9	−0·33641	−0·23603	−0·10398	+0·03975	+0·17239
10	−0·37470	−0·38480	−0·34553	−0·26098	−0·14220
11	−0·19887	−0·29472	−0·35672	−0·37649	−0·35014
12	+0·06218	−0·06237	−0·17766	−0·27340	−0·33925
13	+0·30548	+0·19149	+0·07246	−0·04683	−0·15873

Bessel Functions of Half-integral Order.

The solution of the equation

$$\frac{d^2u_n}{dx^2} + \left\{ 1 - \frac{n(n+1)}{x^2} \right\} u_n = 0$$

being taken in the symbolical form

$$u_n = x^{n+1}\left(- \frac{1}{x}\frac{d}{dx}\right)^n \frac{Ae^{-ix} + Be^{+ix}}{x}$$

yields as standard functions of real quantities

$$S_n(x) = x^{n+1} \left(- \frac{1}{x}\frac{d}{dx}\right)^n \frac{\sin x}{x}$$

$$C_n(x) = x^{n+1} \left(- \frac{1}{x}\frac{d}{dx}\right)^n \frac{\cos x}{x},$$

with $$E_n(x) = x^{n+1} \left(- \frac{1}{x}\frac{d}{dx}\right)^n \frac{e^{-ix}}{x} = C_n(x) - i\, S_n(x)$$

as an important associated function.

The functions $(E_n(x))^2 = (S_n(x))^2 + (C_n(x))^2$

$$(E_n'(x))^2 = (S_n'(x))^2 + (C_n'(x))^2$$

are of importance, and have been tabulated with $S_n(x)$, $C_n(x)$, and their derivatives $S_n'(x)$, $C_n'(x)$.

The connection with Bessel Functions is apparent from the differential equation, giving

$$S_n(x) = \sqrt{\tfrac{1}{2}\pi x}\, J_{n+\frac{1}{2}}(x)$$

$$C_n(x) = (-1)^n \sqrt{\tfrac{1}{2}\pi(x)}\, J_{-n-\frac{1}{2}}(x).$$

From the differential equation, we obtain

$$S_n'(x) = \frac{n+1}{x} S_n(x) - S_{n+1}(x)$$

$$S_n'(x) = S_{n-1}(x) - \frac{n}{x} S_n(x)$$

with corresponding formulæ for $C_n'(x)$, $E_n'(x)$.

By elimination of $S_n'(x)$, we get the recurrence formula

$$S_{n+1}(x) = \frac{2n+1}{x} S_n(x) - S_{n-1}(x).$$

Bessel Functions of Half-integral Order.

n	$S_n(1)$	$C_n(1)$	$[E_n(1)]^2$	n
0	·8414710	·5403023	1·0	0
1	·3011687	1·3817733	2·0	1
2	·0620351	3·605018	13·0	2
3	·0090066	16·64331	277·0	3
4	·0010110	112·8982		
5	·0000926	999·4403		
6	·0000072	10880·95		
7	·0000005	140452·8		

n	$S_n'(1)$	C ′(1)	$[E_n'(1)]^2$	n
0	·5403023	—·8414710	1·0	0
1	·5403023	—·8414710	1·0	1
2	·1770986	—5·828262	34·0	2
3	·0350153	—46·32493	2146·0	3
4	·0049625	—434·9494		
5	·0005482	—4884·304		
6	·0000496	—64286·23		
7	·0000038	—972289·0		

n	Log. $[S_n(1)]$	Log. $[C_n(1)]$	Log. $[E_n(1)]^2$	n
0	$\bar{1}$·9250391	$\bar{1}$·7326368	·0000000	0
1	$\bar{1}$·4788098	·1404368	·3010300	1
2	$\bar{2}$·7926371	·5569074	1·1139434	2
3	$\bar{3}$ 9545600	1·2212399	2·4424798	3
4	$\bar{3}$·0047580	2·0526869		

n	Log. $[S_n'(1)]$	Log. $[C_n'(1)]$	Log. $[E_n'(1)]^2$	n
0	$\bar{1}$·7326368	$\bar{1}$·9250391	·0000000	0
1	$\bar{1}$·7326368	$\bar{1}$·9250391	·0000000	1
2	$\bar{1}$·2482150	·7655390	1·5314789	2
3	$\bar{2}$·5442579	1·6658147	3·3316297	3
4	$\bar{3}$·6957021	2·6384387		

n	$S_n(2)$	$C_n(2)$	$[E_n(2)]^2$	n
0	·9092974	—·4161468	1·000000	0
1	·8707955	·7012240	1·250000	1
2	·3968959	1·4679828	2·312500	2
3	·1214442	2·968733	8·828125	3
4	·0281588	8·922583	79·61328	4
5	·0052703	37·18289	1382·567	5
6	·0008281	195·5833		
7	·0001122	1234·109		
8	·0000134	9060·232		
9	·0000014	75777·86		
10	·0000001	710829·4		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(2)$	$C_n'(2)$	$[E_n'(2)]^2$	n
0	—·4161468	—·9092974	1·0000000	0
1	·4738997	—·7667588	·8125000	1
2	·4738997	—·7667588	·8125000	2
3	·2147296	—2·985117	8·957031	3
4	·0651266	—14·87643	221·3125	4
5	·0149829	—84·03464	7061·821	5
6	·0027861	—549·5671		
7	·0004354	—4123·797		
8	·0000587	—35006·82		
9	·0000070	—331940·1		
10	·0000007	—3478369·		

n	Log. $[S_n(2)]$	Log. $[C_n(2)]$	Log. $[E_n(2)]^2$	n
0	$\bar{1}$·9587060	$\bar{1}$·6192466	·0000000	0
1	$\bar{1}$·9399162	$\bar{1}$·8458568	·0969100	1
2	$\bar{1}$·5986767	·1667210	·3640817	2
3	$\bar{1}$·0843767	·4725711	·9458684	3
4	$\bar{2}$·4496139	·9504906	1·9009855	4
5	$\bar{3}$·7218386	1·5703431	3·1406862	5
6	$\bar{4}$·9180733	2·2913318		

n	Log. $[S_n'(2)]$	Log. $[C_n'(2)]$	Log. $[E_n'(2)]^2$	n
0	$\bar{1}$·6192466	$\bar{1}$·9587060	·0000000	0
1	$\bar{1}$·6756864	$\bar{1}$·8846588	$\bar{1}$·9098234	1
2	$\bar{1}$·6756864	$\bar{1}$·8846588	$\bar{1}$·9098234	2
3	$\bar{1}$·3318919	·4749613	·9521642	3
4	$\bar{2}$·8137585	1·1724988	2·3450059	4
5	$\bar{2}$·1755970	1·9244583	3·8489167	5
6	$\bar{3}$·4449957	2·7400207		

n	$S_n(3)$	$C_n(3)$	$[E_n(3)]^2$	n
0	·1411200	—·9899925	1·0000000	0
1	1·0370325	—·1888775	1·1111111	1
2	·8959125	·8011150	1·4444444	2
3	·4561550	1·5240692	2·530864	3
4	·1684491	2·755046	7·618656	4
5	·0491924	6·741070	45·44444	5
6	·0119231	21·96221	482·3389	6
7	·0024745	88·42851		
8	·0004495	420·1803		
9	·0000726	2292·593		
10	·0000106	14099·58		
11	·0000014	96404·45		
12	·0000002	725001·2		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(3)$	$C_n'(3)$	$[E_n'(3)]^2$	n
0	—·9899925	—·1411200	1·0000000	0
1	—·2045575	—·9270333	·9012346	1
2	·4397575	—·7229542	·7160494	2
3	·4397575	—·7229542	·7160494	3
4	·2315561	—2·149326	4·673220	4
5	·0864617	—8·480070	71·91907	5
6	·0253460	—37·18335	1382·602	6
7	·0061492	—184·3710		
8	·0012759	—1032·052		
9	·0002316	—6457·600		
10	·0000374	—44705·00		
11	·0000054	—339383·4		
12	·0000007	—2803600·		

n	Log. $[S_n(3)]$	Log. $[C_n(3)]$	Log. $[E_n(3)]^2$	n
0	$\bar{1}$·1495886	$\bar{1}$·9956319	·0000000	0
1	·0157924	$\bar{1}$·2761801	·0457574	1
2	$\bar{1}$·9522656	1·9036949	·1597008	2
3	$\bar{1}$·6591125	·1830046	·4032688	3
4	$\bar{1}$·2264687	·4401289	·8818784	4
5	$\bar{2}$·6918984	·8287288	1·6574808	5
6	$\bar{2}$·0763909	1·3416761	2·6833523	6
7	$\bar{3}$·3934926	1·9465923		

n	Log. $[S_n'(3)]$	Log. $[C_n'(3)]$	Log. $(E_n'(3))^2$	n
0	$\bar{1}$·9956319	$\bar{1}$·1495886	·0000000	0
1	$\bar{1}$·3108155	$\bar{1}$·9670954	$\bar{1}$·9548378	1
2	$\bar{1}$·6432133	$\bar{1}$·8591108	$\bar{1}$·8549430	2
3	$\bar{1}$·6432133	$\bar{1}$·8591108	$\bar{1}$·8549430	3
4	$\bar{1}$·3646563	·3323022	·6696163	4
5	$\bar{2}$·9368240	·9283995	1·8568440	5
6	$\bar{2}$·4039119	1·5703485	3·1406973	6
7	$\bar{3}$·7888217	2·2656927		

n	$S_n(4)$	$C_n(4)$	$[E_n(4)]^2$	n
0	—·7568025	—·6536436	1·0000000	0
1	·4644430	—·9202134	1·0625000	1
2	1·1051347	—·0365164	1·2226562	2
3	·9169754	·8745679	1·6057129	3
4	·4995723	1·5670102	2·705093	4
5	·2070622	2·6512051	7·071763	5
6	·0698487	5·7238037	32·76681	6
7	·0199460	15·95116	254·4398	7
8	·0049490	54·09304	2926·056	8
9	·0010870	213·9442		
10	·0002144	962·1421		
11	·0000384	4837·302		
12	·0000063	26852·34		
13	·0000009	162989·8		
14	·0000001	1073329·		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(4)$	$C_n'(4)$	$[E_n'(4)]^2$	n
0	—·6536436	+·7568025	1·0000000	0
1	—·8729132	—·4235903	·9414062	1
2	—·0881244	—·9019552	·8212891	2
3	·4174032	—·6924423	·6537018	3
4	·4174032	—·6924423	·6537018	4
5	·2407446	—1·746996	3·109954	5
6	·1022891	—5·934501	35·22876	6
7	·0349431	—22·19072	492·4293	7
8	·0100481	—92·23491	8507·279	8
9	·0025032	—427·2815		
10	·0005511	—2191·411		
11	·0001088	—12340·44		
12	·0000195	—75719·73		
13	·0000032	—502864·7		
14	·0000005	—3593662·		

n	Log. $[S_n(4)]$	Log. $[C_n(4)]$	Log. $[E_n(4)]^2$	n
0	$\bar{1}$·8789825	$\bar{1}$·8153410	·0000000	0
1	$\bar{1}$·6669324	$\bar{1}$·9638885	·0263289	1
2	0·0434153	$\bar{2}$·5624884	·0873043	2
3	$\bar{1}$·9623577	$\bar{1}$·9417935	·2056678	3
4	$\bar{1}$·6985983	0·1950719	·4321823	4
5	$\bar{1}$·3161007	·4234433	·8495276	5
6	$\bar{2}$·8441582	·7576848	1·5154341	6
7	$\bar{2}$·2998566	1·2027922	2·4055851	7
8	$\bar{3}$·6945133	1·7331414	3·4662827	8
9	$\bar{3}$·0362346	2·3303006		

n	Log. $[S_n(4)]$	Log. $[C_n'(4)]$	Log. $[(E_n'(4)]^2$	n
0	$\bar{1}$·8153410	$\bar{1}$·8789825	0·0000000	0
1	$\bar{1}$·9409711	$\bar{1}$·6269460	1·9737771	1
2	$\bar{2}$·9450960	$\bar{1}$·9551850	$\bar{1}$·9144960	2
3	$\bar{1}$·6205557	$\bar{1}$·8403836	$\bar{1}$·8153797	3
4	$\bar{1}$·6205557	$\bar{1}$·8403836	$\bar{1}$·8153797	4
5	$\bar{1}$·3815565	·2422918	·4927540	5
6	$\bar{1}$·0098296	·7733841	1·5468972	6
7	$\bar{2}$·5433616	1·3461714	2·6923439	7
8	$\bar{2}$·0020852	1·9648953	3·9297907	8
9	$\bar{3}$·3984910	2·6307141		

Bessel Functions of Half-integral Order—continued.

n	$S_n(5)$	$C_n(5)$	$[E_n(5)]^2$	n
0	—·9589243	·2836622	1·0000000	0
1	—·4754470	—·9021918	1·0400000	1
2	·6736561	—·8249773	1·1344000	2
3	1·1491031	·0772145	1·3263999	3
4	·9350883	·9330777	1·7450241	4
5	·5340558	1·6023252	2·852662	5
6	·2398345	2·592038	6·776181	6
7	·0895139	5·136973	26·39650	7
8	·0287072	12·81888	164·3244	8
9	·0080905	38·44722		
10	·0020367	133·2806		
11	·0004637	521·3312		
12	·0000964	2264·843		
13	·0000185	10802·88		
14	·0000033	56071·73		
15	·0000005	314413·1		
16	·0000001	1893290·		

n	$S_n'(5)$	$C_n'(5)$	$[E'(5_n)]^2$	n
0	·2836622	·9589243	1·0000000	0
1	—·8638349	·4641006	·9616000	1
2	—·7449095	—·5722009	·8823040	2
3	—·0158058	—·8713060	·7594240	3
4	·4010325	—·6692476	·6087194	4
5	·4010325	—·6692476	·6087194	5
6	·2462544	—1·5081202	2·335068	6
7	·1145151	—4·599725	21·17059	7
8	·0435824	—15·37324	236·3383	8
9	·0141443	—56·38612		
10	·0040171	—228·1139		
11	·0010165	—1013·648		
12	·0002323	—4912·292		
13	·0000484	—25823·65		
14	·0000093	—146197·9		
15	·0000017	—887167·7		
16	·0000003	—5744114·		

n	Log. $[S_n(5)]$	Log. $[C_n(5)]$	Log. $[E_n(5)]^2$	n
0	$\bar{1}$·9817843	$\bar{1}$·4528015	·0000000	0
1	$\bar{1}$·6771021	$\bar{1}$·9552989	·0170333	1
2	$\bar{1}$·8284378	$\bar{1}$·9164420	·0547662	2
3	·0603589	$\bar{2}$·8876992	·1226745	3
4	$\bar{1}$·9708527	$\bar{1}$·9699178	·2418014	4
5	$\bar{1}$·7275867	·2047506	·4552503	5
6	$\bar{1}$·3799116	·4136413	·8309850	6
7	$\bar{2}$·9518904	·7107073	1·4215464	7
8	$\bar{2}$·4579904	1·1078501	2·2157021	8
9	$\bar{3}$·9079754	1·5848650		
10	$\bar{3}$·3089316	2·1247668		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(5)]$	Log. $[C_n'(5)]$	Log. $[E_n'(5)]^2$	n
0	$\bar{1}$·4528015	$\bar{1}$·9817843	·0000000	0
1	$\bar{1}$·9364307	$\bar{1}$·6666121	$\bar{1}$·9829945	1
2	$\bar{1}$·8721035	$\bar{1}$·7575486	$\bar{1}$·9456183	2
3	$\bar{2}$·1988166	$\bar{1}$·9401707	$\bar{1}$·8804846	3
4	$\bar{1}$·6031796	$\bar{1}$·8255868	$\bar{1}$·7844172	4
5	$\bar{1}$·6031796	$\bar{1}$·8255868	$\bar{1}$·7844172	5
6	$\bar{1}$·3913840	·1784359	·3682996	6
7	$\bar{1}$·0588626	·6627318	1·3257329	7
8	$\bar{2}$·6393112	1·1867653	2·3735342	8
9	$\bar{2}$·1505807	1·7511723		
10	$\bar{3}$·6039080	2·3581517		

n	$S_n(6)$	$C_n(6)$	$[E_n(6)]^2$	n
0	−·2794155	·9601703	1·0000000	0
1	−1·0067395	−·1193871	1·0277778	1
2	−·2239543	−1·0198638	1·0902778	2
3	·8201110	−·7304994	1·2062114	3
4	1·1807504	·1676145	1·4222661	4
5	·9510146	·9819212	1·8685981	5
6	·5627764	1·6325743	2·982016	6
7	·2683343	2·5553232	6·601680	7
8	·1080593	4·755734	22·62868	8
9	·0378337	10·91926	119·2316	9
10	·0117474	29·82191	889·3466	10
11	·0032822	93·45743		
12	·0008345	328·4316		
13	·0001948	1275·007		
14	·0000420	5409·102		
15	·0000084	24868·98		
16	·0000016	123080·6		
17	·0000003	652074·6		

n	$S_n'(6)$	$C_n'(6)$	$[E_n'(6)]^2$	n
0	·9601703	·2794155	1·0000000	0
1	−·1116256	·9800681	·9729938	1
2	−·9320881	·2205675	·9174383	2
3	−·6340098	−·6546141	·8304880	3
4	·0329440	−·8422424	·7104576	4
5	·3882382	−·6506531	·5740783	5
6	·3882382	−·6506531	·5740783	6
7	·2497198	−1·3486361	1·8811792	7
8	·1242552	−3·785655	14·34662	8
9	·0513087	−11·62315	135·1002	9
10	·0182547	−38·78393	1504·193	10
11	·0057300	−141·5167		
12	·0016133	−563·4057		
13	·0004125	−2434·084		
14	·0000967	−11346·23		
15	·0000197	−56763·36		
16	·0000040	−303346·1		
17	·0000008	−1833143·		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n(6)]$	Log. $[C_n(6)]$	Log. $[E_n(6)]^2$	n
0	$\bar{1}$·4462504	$\bar{1}$·9823482	·0000000	0
1	·0029172	$\bar{1}$·0769574	·0118993	1
2	$\bar{1}$·3501593	·0085422	·0375371	2
3	$\bar{1}$·9138726	$\bar{1}$·8636199	·0814234	3
4	·0721581	$\bar{1}$·2243116	·1529808	4
5	$\bar{1}$·9781872	$\bar{1}$·9920766	·2715159	5
6	$\bar{1}$·7503359	·2128730	·4745099	6
7	$\bar{1}$·4286762	·4074458	·8196545	7
8	$\bar{1}$·0336621	·6772176	1·3546592	8
9	$\bar{2}$·5778788	1·0381930	2·0763912	9
10	$\bar{2}$·0699421	1·4745354	2·9490710	10
11	$\bar{3}$·5161693	1·9706139	3·9412276	11

n	Log. $[S_n'(6)]$	Log. $[C_n'(6)]$	Log. $[E_n'(6)]^2$	n
0	$\bar{1}$·9823482	$\bar{1}$·4462504	·0000000	0
1	$\bar{1}$·0477638	$\bar{1}$·9912562	$\bar{1}$·9881101	1
2	$\bar{1}$·9694570	$\bar{1}$·3435416	$\bar{1}$·9625768	2
3	$\bar{1}$·8020960	$\bar{1}$·8159854	$\bar{1}$·9193334	3
4	$\bar{2}$·5177768	$\bar{1}$·9254370	$\bar{1}$·8515380	4
5	$\bar{1}$·5890982	1·8133495	$\bar{1}$·7589712	5
6	$\bar{1}$·5890982	$\bar{1}$·8133495	$\bar{1}$·7589712	6
7	$\bar{1}$·3974530	·1298948	·2744302	7
8	$\bar{1}$·0943146	·5781411	1·1567497	8
9	$\bar{2}$·7101914	1·0653238	2·1306561	9
10	$\bar{2}$·2613742	1·5886518	3·1773036	10
11	$\bar{3}$·7581532	2·1508077		

n	$S_n(7)$	C(7)	$[E_n(7)]^2$	n
0	·6569866	·7539023	1·0000000	0
1	—·6600470	·7646869	1·0204082	1
2	—·9398639	—·4261793	1·0649730	2
3	—·0112843	—1·0691007	1·1431036	3
4	·9285796	—·6429214	1·2756080	4
5	1·2051723	·2424875	1·5112406	5
6	·9652627	1·0239731	1·9802530	6
7	·5874584	1·6591769	3·097975	7
8	·2935767	2·531406	6·494203	8
9	·1255135	4·488523	20·16258	9
10	·0471029	9·651729	93·15808	10
11	·0157952	24·46666	598·6178	11
12	·0047955	70·73873		
13	·0013317	228·1717		
14	·0003410	809·3520		
15	·0000811	3124·858		
16	·0000180	13029·31		
17	·0000037	58299·01		
18	·0000007	278465·7		
19	·0000001	1413591·		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(7)$	$C_n'(7)$	$[E_n'(7)]^2$	n
0	·7539023	−·6569866	1·0000000	0
1	·7512790	+·6446613	·9800082	1
2	−·3915145	+·8864524	·9390815	2
3	−·9350278	+·0320067	·8753014	3
4	−·5419012	−·7017170	·7860638	4
5	·0677422	−·8161267	·6706518	5
6	·3778043	−·6352038	·5462200	6
7	·3778043	−·6352038	·5462200	7
8	·2519422	−1·2338585	1·585882	8
9	·1322021	−3·239553	10·51218	9
10	·0582237	−9·299661	86·48708	10
11	·0222819	−28·79588	829·2033	11
12	·0075743	−96·79974		
13	·0023224	−353·0087		
14	·0006497	−1390·532		
15	·0001673	−5886·773		
16	·0000400	−26656·41		
17	·0000089	−128544·0		
18	·0000019	−657755·8		
19	·0000004	−3558425·		

n	Log. $[S_n(7)]$	Log. $[C_n(7)]$	Log $[E_n(7)]^2$	n
0	$\bar{1}$·8175564	$\bar{1}$·8773150	·0000000	0
1	$\bar{1}$·8195749	$\bar{1}$·8834836	·0087739	1
2	$\bar{1}$·9730650	$\bar{1}$·6295924	·0273386	2
3	$\bar{2}$·0524737	·0290186	·0580857	3
4	$\bar{1}$·9678191	$\bar{1}$·8081579	·1057172	4
5	·0810491	$\bar{1}$·3846893	·1793337	5
6	$\bar{1}$ 9846455	·0102885	·2967208	6
7	$\bar{1}$·7689771	·2198927	·4910780	7
8	$\bar{1}$·4677215	·4033618	·8125259	8
9	$\bar{1}$·0986904	·6521034	1·3045461	9
10	$\bar{2}$·6730476	·9846051	1·9692206	10
11	$\bar{2}$·1985243	1·3885748	2·7771497	11
12	$\bar{3}$·6808361	1·8496573		
13	$\bar{3}$·1244043	2·3582617		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(7)]$	Log. $[C_n'(7)]$	Log. $[E_n'(7)]^2$	n
0	$\bar{1}$·8773150	$\bar{1}$·8175564	·0000000	0
1	$\bar{1}$·8758012	$\bar{1}$·8093316	$\bar{1}$·9912297	1
2	$\bar{1}$·5927478	$\bar{1}$·9476554	$\bar{1}$·9727033	2
3	$\bar{1}$·9708245	$\bar{2}$·5052413	$\bar{1}$·9421576	3
4	$\bar{1}$·7339202	$\bar{1}$·8461593	$\bar{1}$·8954578	4
5	$\bar{2}$·8308592	$\bar{1}$·9117576	$\bar{1}$·8264970	5
6	$\bar{1}$·5772670	$\bar{1}$·8029131	$\bar{1}$·7373676	6
7	$\bar{1}$·5772670	$\bar{1}$·8029131	$\bar{1}$·7373676	7
8	$\bar{1}$·4013009	·0912654	·2002709	8
9	$\bar{1}$·1212385	·5104850	1·0216928	9
10	$\bar{2}$·7650977	·9684671	1·9369512	10
11	$\bar{2}$·3479526	1·4593304	2·9186610	11
12	$\bar{3}$·8793411	1·9858742		
13	$\bar{3}$·3659326	2·5477854		

n	$S_n(8)$	$C_n(8)$	$[E_n(8)]^2$	n
0	·9893582	—·1455000	1·0000000	0
1	·2691698	·9711707	1·0156250	1
2	—·8884196	·5096891	1·0490725	2
3	—·8244320	—·6526151	1·1055944	3
4	·1670415	—1·0807273	1·1958744	4
5	1·0123538	—·5632031	1·3420578	5
6	1·2249449	·3063230	1·5943238	6
7	·9781817	1·0609780	2·082514	7
8	·6091458	1·6830107	3·203583	8
9	·3162531	2·515420	6·427352	9
10	·1419553	4·291111	18·43378	10
11	·0563796	8·748747	76·54376	11
12	·0201360	20·86154	435·2041	12
13	·0065454	56·44356		
14	·0019547	169·6355		
15	·0005403	558·4850		
16	·0001391	1994·494		
17	·0000335	7668·802		
18	·0000076	31556·52		
19	·0000016	138280·1		
20	·0000003	642558·9		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(8)$	$C_n'(8)$	$[E_n'(8)]^2$	n
0	—·1455000	—·9893582	1·0000000	0
1	·9557120	—·2668964	·9846190	1
2	·4912747	·8437485	·9532622	2
3	—·5792575	·7544197	·9046883	3
4	—·9079528	—·1122515	·8369787	4
5	—·4656796	—·7287253	·7478982	5
6	·0936451	—·7929453	·6375318	6
7	·3690359	—·6220327	·5231121	7
8	·3690359	—·6220327	·5231121	8
9	·2533611	—1·1468365	1·379426	9
10	·1388090	—2·848469	8·133044	10
11	·0644334	—7·738416	59·88724	11
12	·0261760	—22·54356	508·2127	12
13	·0094997	—70·85924		
14	·0031247	—240·4185		
15	·0009416	—877·5239		
16	·0002621	—3430·503		
17	·0000679	—14301·71		
18	·0000165	—63333·36		
19	·0000038	—296858·7		
20	·0000008	—1468117·		

n	Log. $[S_n(8)]$	Log. $[C_n(8)]$	Log. $[E_n(8)]$	n
0	$\bar{1}$·9953536	$\bar{1}$·1628630	0·0000000	0
1	$\bar{1}$·4300263	$\bar{1}$·9872956	·0067334	1
2	$\bar{1}$·9486181	$\bar{1}$·7073053	·0208055	2
3	1·9161549	$\bar{1}$·8146570	·0435958	3
4	$\bar{1}$·2228244	·0337162	·0776855	4
5	·0053323	$\bar{1}$·7506650	·1277712	5
6	·0881165	$\bar{1}$·4861797	·2025765	6
7	$\bar{1}$·9904195	·0257063	·3185878	7
8	$\bar{1}$·7847213	·2260868	·5056360	8
9	$\bar{1}$·5000347	·4006105	·8080321	9
10	$\bar{1}$·1521516	·6325697	1·2656145	10
11	$\bar{2}$·7511219	·9419459	1·8839098	11
12	$\bar{2}$·3039729	1·3193463	2·6386930	12
13	$\bar{3}$·8159352	1·7516144		
14	$\bar{3}$·2910760	2·2295167		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(8)]$	Log. $[C_n'(9)]$	Log. $[E_n'(8)]^2$	n
0	$\bar{1}$·1628630	$\bar{1}$·9953536	·0000000	0
1	$\bar{1}$·9803270	$\bar{1}$·4263426	$\bar{1}$·9932682	1
2	$\bar{1}$·6913243	$\bar{1}$·9262130	$\bar{1}$·9792124	2
3	$\bar{1}$·7628717	$\bar{1}$·8776130	$\bar{1}$·9564990	3
4	$\bar{1}$·9580633	$\bar{1}$·0501919	$\bar{1}$·9227145	4
5	$\bar{1}$·6680872	$\bar{1}$·8625639	$\bar{1}$·8738424	5
6	$\bar{2}$·9714850	$\bar{1}$·8992433	$\bar{1}$·8045018	6
7	$\bar{1}$·5670687	$\bar{1}$·7938132	$\bar{1}$·7185948	7
8	$\bar{1}$·5670687	$\bar{1}$·7938132	$\bar{1}$·7185948	8
9	$\bar{1}$·4037399	·0595015	0·1396984	9
10	$\bar{1}$·1424175	·4546115	·9102531	10
11	$\bar{2}$·8091109	·8886521	1·7773344	11
12	$\bar{2}$·4178966	1·3530225	2·7060455	12
13	$\bar{3}$·9777117	1·8503964		
14	$\bar{3}$·4948071	2·3809678		

n	$S_n(9)$	$C_n(9)$	$[E_n(9)]^2$	n
0	·4121185	—·9111303	1·0000000	0
1	·9569212	·3108818	1·0123457	1
2	—·0931448	1·0147575	1·0384086	2
3	—1·0086683	·2528724	1·0813561	3
4	—·6913750	—·8180790	1·1472525	4
5	·3172933	—1·0709514	1·2476118	5
6	1·0791779	—·4908616	1·4055701	6
7	1·2415193.	·3619291	1·6723628	7
8	·9900209	1·0940767	2·177146	8
9	·6285202	1·7046603	3·300904	9
10	·3368550	2·504651	6·386745	10
11	·1574749	4·139524	17·16046	11
12	·0655808	8·074134	65·19594	12
13	·0246941	18·28863	3344·745	13
14	·0085014	46·79174	21894·67	14
15	·0026992	132·4848		
16	·0007959	409·5447		
17	·0002192	1369·179		
18	·0000567	4915·041		
19	·0000138	18837·10		
20	·0000032	76712·39		
21	·0000007	330630·4		
22	·0000001	1502966·		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(9)$	$C_n'(9)$	$[E_n'(9)]^2$	n
0	—·9111303	—·4121185	1·0000000	0
1	·3057939	—·9456727	·9878066	1
2	·9776200	·0853801	·9630307	2
3	·2430780	·9304667	·9248551	3
4	—·7013905	·6164631	·8719753	4
5	—·8676491	—·2231060	·8025912	5
6	—·4021587	—·7437103	·7148366	6
7	·1135518	—·7723620	·6094370	7
8	·3615007	—·6105836	·5034950	8
9	·3615007	—·6105836	·5034950	9
10	·2542368	—1·0782848	1·227334	10
11	·1443857	—2·554768	6·547686	11
12	·0700338	—6·625988	43·90862	12
13	·0299116	—18·34277	336·4581	13
14	·0114697	—54·49853	2970·090	14
15	·0040027	—174·0162		
16	·0012842	—595·5946		
17	·0003818	—2176·682		
18	·0001059	—8460·902		
19	·0000275	—34852·17		
20	·0000068	—151634·87		
21	·0000016	—694758·6		
22	·0000003	—3343287·		

n	Log. $[S_n(9)]$	Log. $[C_n(9)]$	Log. $[E_n(9)]^2$	n
0	$\bar{1}$·6150221	$\bar{1}$·9595804	0·0000000	0
1	$\bar{1}$·9808761	$\bar{1}$·4925953	·0053288	1
2	$\bar{2}$·9691584	·0063623	·0163683	2
3	·0037484	$\bar{1}$·4029014	·0339688	3
4	$\bar{1}$·8397137	$\bar{1}$·9127952	·0596590	4
5	$\bar{1}$·5014608	·0297698	·0960795	5
6	·0330930	$\bar{1}$·6909590	·1478524	6
7	·0939534	$\bar{1}$·5586235	·2233305	7
8	$\bar{1}$·9956444	·0390477	·3378876	8
9	$\bar{1}$·7983192	·2316378	·5186329	9
10	$\bar{1}$·5274431	·3987471	·8052796	10
11	$\bar{1}$·1972113	·6169504	1·2345289	11
12	$\bar{2}$·8167769	·9070959	1·8142206	12
13	$\bar{2}$·3925925	1·2621811	2·5243630	13
14	$\bar{3}$·9294886	1·6701692	3·3403384	14
15	$\bar{3}$·4312382	2·1221659		
16	$\bar{4}$·9008836	2·6123012		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(9)]$	Log. $[C_n'(9)]$	Log. $[E_n'(9)]^2$	n
0	$\bar{1}$·9595804	$\bar{1}$·6150221	·0000000	0
1	$\bar{1}$·4854289	$\bar{1}$·9757408	$\bar{1}$·9946719	1
2	$\bar{1}$·9901701	$\bar{2}$·9313568	$\bar{1}$·9836401	2
3	$\bar{1}$·3857457	$\bar{1}$·9687008	$\bar{1}$·9660737	3
4	1·8459599	$\bar{1}$·7899070	$\bar{1}$·9405042	4
5	1·9383441	$\bar{1}$·3485112	$\bar{1}$·9044943	5
6	1·6043974	$\bar{1}$·8714038	$\bar{1}$·8542069	6
7	$\bar{1}$·0551940	$\bar{1}$·8878209	$\bar{1}$·7849288	7
8	$\bar{1}$·5581092	$\bar{1}$·7857452	$\bar{1}$·7019951	8
9	$\bar{1}$·5581092	$\bar{1}$·7857452	$\bar{1}$·7019951	9
10	$\bar{1}$·4052385	·0327335	·0889627	10
11	$\bar{1}$·1595242	·4073515	·8160879	11
12	$\bar{2}$·8453076	·8212507	1·6425498	12
13	$\bar{2}$·4758399	1·2634649	2·5269309	13
14	$\bar{2}$·0595528	1·7363848		
15	3·6023493	2·2405896		
16	3·1086340	2·7749508		

n	S (10)	$C_n(10)$	$[E_n(10)]^2$	n
0	—·5440211	—·8390715	1·0000000	0
1	·7846694	—·6279283	1·0100000	1
2	·7794219	·6506930	1·0309000	2
3	—·3949584	·9532748	1·0647250	3
4	—1·0558929	·0165993	1·1151852	4
5	—·5553451	—·9383354	1·1888816	5
6	·4450132	—1·0487683	1·2979516	6
7	1·1338623	—·4250633	1·4663225	7
8	1·2557802	·4111733	1·7460475	8
9	1·0009641	1·1240579	2·265235	9
10	·6460515	1·7245367	3·391409	10
11	·3557441	2·497469	6·363907	11
12	·1721600	4·019643	16·18716	12
13	·0746558	7·551637	57·03279	13
14	·0294108	16·36978	267·9704	14
15	·0106354	39·92072	1593·663	15
16	·0035590	107·3844		
17	·0011094	314·4480		
18	·0003239	993·1834		
19	·0000890	3360·331		
20	·0000231	12112·11		
21	·0000057	46299·30		
22	·0000013	186974·9		
23	·0000003	795087·8		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(10)$	$C_n'(10)$	$[E_n'(10)]^2$	n
0	−·8390715	·5440211	1·0000000	0
1	−·6224881	−·7762787	·9901000	1
2	·6287850	−·7580669	·9700360	2
3	·8979095	·3647106	·9392552	3
4	·0273987	·9466351	·8968684	4
5	−·7782203	·4857670	·8415964	5
6	−·8223531	−·3090745	·7717916	6
7	−·3486904	−·7512239	·6859223	7
8	·1292381	−·7540019	·5852213	8
9	·3549126	−·6004788	·4865378	9
10	·3549126	−·6004788	·4865378	10
11	·2547330	−1·0226794	1·110762	11
12	·1491522	−2·326102	5·432996	12
13	·0751074	−5·797486	33·61647	13
14	·0334807	−15·36605	236·1167	14
15	·0134576	−43·51130	1893·233	15
16	·0049410	−131·8944		
17	·0016730	−427·1771		
18	·0005264	−1473·282		
19	·0001549	−5391·445		
20	·0000428	−20863·88		
21	·0000112	−85116·43		
22	·0000028	−365045·5		
23	·0000007	−1641727·		

n	Log. $[S_n(10)]$	Log. $[C_n(10)]$	Log. $[E_n(10)]^2$	n
0	$\bar{1}$·7356158	$\bar{1}$·9237990	·0000000	0
1	$\bar{1}$·8946867	$\bar{1}$·7979100	·0043214	1
2	1·8917726	$\bar{1}$·8133761	·0132165	2
3	$\bar{1}$·5965514	$\bar{1}$·9792181	·0272375	3
4	0·0236199	$\bar{2}$·2200898	·0473370	4
5	$\bar{1}$·7445630	$\bar{1}$·9723581	·0751386	5
6	$\bar{1}$·6483729	0·0206795	·1132584	6
7	·0545604	$\bar{1}$·6284536	·1662294	7
8	·0989136	$\bar{1}$·6140292	·2420560	8
9	·0004185	0·0507886	·3551134	9
10	$\bar{1}$·8102671	0·2366724	·5303798	10
11	1·5511378	0·3975001	·8037238	11
12	$\bar{1}$·2359323	0·6041873	1·2091707	12
13	$\bar{2}$·8730639	0·8780411	1·7561246	13
14	$\bar{2}$·4685065	1·2140428	2·4280865	14
15	$\bar{2}$·0267549	1·6011983	3·2023961	15
16	3·5513330	2·0309414		
17	$\bar{3}$·0450910	2·4975488		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(10)]$	Log. $[C_n'(10)]$	Log. $[E_n'(10)]^2$	n
0	$\bar{1}$·9237990	$\bar{1}$·7356158	·0000000	0
1	$\bar{1}$·7941311	$\bar{1}$·8900177	$\bar{1}$·9956791	1
2	$\bar{1}$·7985024	$\bar{1}$·8797075	$\bar{1}$·9867879	2
3	$\bar{1}$·9532326	$\bar{1}$·5619484	$\bar{1}$·9727835	3
4	$\bar{2}$·4377299	$\bar{1}$·9761826	$\bar{1}$·9527289	4
5	$\bar{1}$·8911026	$\bar{1}$·6864279	$\bar{1}$·9251039	5
6	$\bar{1}$·9150583	$\bar{1}$·4900631	$\bar{1}$·8875001	6
7	$\bar{1}$·5424400	$\bar{1}$·8757693	$\bar{1}$·8362748	7
8	$\bar{1}$·1113905	$\bar{1}$·8773724	$\bar{1}$·7673201	8
9	$\bar{1}$·5501214	$\bar{1}$·7784977	$\bar{1}$·6871163	9
10	$\bar{1}$·5501214	$\bar{1}$·7784977	$\bar{1}$·6871163	10
11	$\bar{1}$·4060852	0·0097396	·0456210	11
12	$\bar{1}$·1736296	·3666287	·7350394	12
13	$\bar{2}$·8756827	·7632397	1·5265521	13
14	$\bar{2}$·5247951	1·1865623	2·3731267	14
15	$\bar{2}$·1289691	1·6386021	3·2772041	15
16	$\bar{3}$·6938116	2·1202264		
17	$\bar{3}$·2235085	2·6306079		

Binary Canon.—Report of the Committee, consisting of Lt.-Col. ALLAN CUNNINGHAM, R.E. (*Chairman*), Prof. A. E. H. LOVE (*Secretary*), *and* Major P. A. MACMAHON, *appointed for Disposing of Copies of the Binary Canon by presentation to Mathematical Societies.*

THE Committee have sent out fifty-eight copies of the above work to representative Mathematical Societies at home and abroad (thirteen and forty-five respectively) at a cost of 4*l.* 9*s.*, as per enclosed account, and return now the unexpended balance of eleven shillings.

Dynamic Isomerism.—Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Dr. T. M. LOWRY (*Secretary*), Professor SYDNEY YOUNG, Dr. C. H. DESCH, Dr. J. J. DOBBIE, *and* Dr. M. O. FORSTER. (*Drawn up by the Secretary.*)

Anomalous Rotatory Dispersion.

DURING the year much justification has been found for the view expressed in the Report presented at Birmingham 'that a knowledge of the phenomena of dynamic isomerism is essential for the interpretation of optical rotation, especially in the case of liquids which show anomalous rotatory dispersion,' and that 'the study of rotatory

dispersion will open up a new and fruitful field for the investigation of dynamic isomerism.' The importance of this aspect of the subject is shown by the conspicuous part which it played in a general discussion on 'Optical Rotatory Power,' held before the Faraday Society on March 27, 1914, to which the Chairman and Secretary of this Committee contributed papers. Preliminary experiments, which will be described in a subsequent Report, have shown (1) that ethyl tartrate, the typical example of anomalous rotatory dispersion, is probably a mixture, and (2) that nitrocamphor, the typical example of dynamic isomerism, gives rise to anomalous rotatory dispersion in certain solvents.

Dynamic Isomerism, Metamerism, Tautomerism, and Desmotropy.

Attention has recently been directed (*Proc. Chem. Soc.*, April 4, 1914) to the importance of maintaining strict accuracy in the use of terms to describe the phenomena of reversible isomeric change.

Briefly, it may be said that all the essential facts in reference to the conception of *equilibrium between isomerides* are set out in Butlerow's classical, but almost forgotten, paper, 'Ueber Isodibutylen' (*Annalen*, 1877, **189**, 44). The name *dynamic isomerism* was introduced in 1899 (*Trans. Chem. Soc.*, **75**, 235) as a paraphrase of Butlerow's description of 'a condition of equilibrium depending on incessant isomeric change'; but the adjective *isodynamic* had already been suggested by Armstrong in 1889 (*Watts' Dictionary*, 'Isomerism') to describe those isomerides 'which change their type with exceptional facility in the course of chemical interchanges.' The word *metameric* had been used in this sense in 1833 by Berzelius to describe isomerides which were readily converted into one another, but the usefulness of the word was destroyed by a misguided attempt to transfer it to another usage.

The hypothesis of *tautomerism* was introduced by Laar in 1885 (*Ber.* **18**, 648; **19**, 730) to account for the facts which had already (as time has shown) been explained adequately by Butlerow. Laar asserts that, in every case of tautomerism, the different formulæ suggested by the reactions of the substance represent, 'not isomeric, but identical bodies'; the term cannot, therefore, be applied to any case of isomerism, however readily the isomerides may be converted into one another.

It is impossible to say whether tautomerism exists; but it has at least been proved by the work of Knorr that the two substances represented by the formulæ

$$CH_3{\cdot}CO{\cdot}CH_2{\cdot}CO_2Et \text{ and } CH_3{\cdot}C(OH){:}CH{\cdot}CO_2Et$$

are not tautomeric, but have a real existence as well-defined isomeric compounds, which only change into one another under definite physical and chemical conditions.

The word *desmotropy* was introduced by Jacobson (*Ber.* 1887, **20**, 1732, footnote; 1888, **21**, 2628, footnote) in 1887, when it had become evident that Laar's theory of tautomerism had broken down in the very case to which it had been most frequently applied, namely, the labile isomerism which results from the contiguity of a double bond and an acidic hydrogen atom. Jacobson considered 'that the known

forms of such compounds are to be represented by a definite grouping of atoms, which in certain reactions passes over into an isomeric grouping by a rearrangement of bonds consequent upon the displacement of a hydrogen atom '; it was to express this view that the word ' desmotropy ' was introduced. If used in this sense, to describe the labile isomerism produced by the mobility of a hydrogen atom, it might be of real value; unfortunately the meaning of the word was tampered with by Hantzsch and Hermann (*Ber.* 1887, **20**, 2802), and, as an inevitable consequence, it has become ambiguous, and has ceased to be clearly significant.

Nearly all the cases to which the word ' tautomerism ' has been misapplied in recent years are examples of isomerism pure and simple, the only special feature being the fact that the isomerides can be converted into one another with greater or less ease. It is therefore very rarely necessary to use any other words than ' isomerism ' and ' isomeric change ' to describe the phenomena. Isomeric compounds which owe their lability to a mobile hydrogen atom might well be distinguished as ' desmotropic ' but for the ambiguity arising from the ill-advised action of Hantzsch in attempting to extend the meaning of this term. At the present time the least ambiguous phrase that can be used to distinguish ethyl acetoacetate and its allies from the very much larger group of substances which exhibit ' dynamic isomerism ' or reversible isomeric change is to refer to them as examples of ' keto-enol ' isomerism, and in other cases to use some similar specific name, describing the nature of the two compounds between which a condition of equilibrium may exist.

Isomeric Halogen-derivatives of Camphor.

Another fruitful, though expensive, line of research has been opened out during the year by applying the process of dynamic isomerism to the preparation of new halogen-derivatives of camphor. A new isomeride has been prepared from α-chlorocamphor by acting on it with alkali, in order to produce a condition of dynamic isomerism in the liquid, and then arresting the isomeric change by the addition of acid. On freezing the alcoholic solution, most of the original substance crystallises out, and the mother-liquor contains the isomeric α-chlorocamphor. This melts at 117° (instead of 94°) and has $[\alpha]_D + 41°$ (instead of +97°). As the new compound can be prepared readily on a large scale, it promises to be of great value in studying the type of dynamic isomerism in which a catalytic agent must be added deliberately in order to bring about a condition of equilibrium between isomers. The whole series of compounds which is now under investigation will provide valuable data for the study of dynamic isomerism and rotatory dispersion, and for the elucidation of the crystallographic structure of the camphor molecule.

The Committee asks for reappointment with a grant of £40. An increased grant is asked for to cover the heavy cost of the organic preparations referred to in the last section of the Report.

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.—Report of the Committee, consisting of Professor F. S. KIPPING (*Chairman*), Professor K. J. P. ORTON (*Secretary*), Dr. S. RUHEMANN, *and* Dr. J. T. HEWITT.

The Acetylation of Anilines by Acetic Anhydride in the presence of Catalysts.

(With W. H. GRAY, M.Sc.)

THE accelerating action of catalysts on the interaction of acetic anhydride and hydroxy- groups has long been known: it was first observed by Franchimont[1] in the acetylation of cellulose, and was later noted by numerous observers.[2] That catalysts had a similar effect in the action of acetic anhydride on the amino-group seems, however, to have been overlooked until Smith and Orton[3] made the discovery that negatively di-ortho-substituted anilines, such as *s*-tribromoaniline, can be acetylated at great speed at the ordinary temperature in the presence of sulphuric and other acids.

Such anilines are particularly suitable for such an investigation as they react very slowly indeed with acetic anhydride at the ordinary temperature, and at higher temperature mainly yield diacetyl derivatives, $Ar\text{-}NAc_2$; in the presence of a catalyst at low temperatures they yield, on the other hand, the monoacetyl derivative. Anilines with one ortho- position unoccupied form monoacetyl derivatives with such extreme ease that the presence of an acid is of no advantage, but, on the contrary, inhibits the reaction, most probably by forming stable salts which do not react with acetic anhydride.

Such salts as sodium acetate have long been known as catalysts of the acetylation of phenols. We have found that various salts have a similar effect in the case of amines. Ferric salts are as pre-eminent in this capacity as in the bromination of acetic anhydride and other compounds, which we are investigating.

An early attempt (Smith and Orton, *loc. cit.*) to throw light on the mechanism of such catalyses, using *s*-tribromophenol, demonstrated that acids varied greatly in catalytic effect; that the change was a reaction of the second order; that the speed was proportional to the concentration of the catalyst.

To follow quantitatively the interaction of acetic anhydride and a di-ortho negatively substituted aniline has proved a very difficult matter. The small capacity for forming salts, which is an advantage in following the effect of acid catalysis on acetylation, is a barrier to the estimation of unchanged aniline by the diazo- method. Moreover, the slowness with which the anilide is hydrolysed equally prevents estimation of the extent of acetylation.

[1] *Compt. rend.*, 1879, **89**, 711.

[2] Skraup, *Monatsh.* 1898, **19**, 458; Freyss. *Bull. Soc. Ind. Mulhouse*, 1899, **44**; J. Thiele, *Ber.* 1898, **31**, 1249; O. Stillich, *Ber.* 1903, **36**, 3115; 1905, **38**, 124; J. Boeseken, *Recueil des Trav. Chim.*, 1911, **31**, 350.

[3] *Trans. Chem. Soc.* 1908, **93**, 1243; 1909, **95**, 1060.

A most excellent method has now been devised for determining the amount of unchanged aniline. This consists in stopping the reaction by adding anhydrous sodium acetate, equivalent to the acid catalyst, followed by some excess of an acetic acid solution of nitric acid. The aniline is rapidly and quantitatively converted into a nitroamine (Orton[4]; W. H. Gray[5]). The nitroamine is completely extracted from the diluted solution by shaking three times with chloroform, and its quantity measured by titration of its alcoholic solution with baryta. The composition of the system could also be checked by direct estimation of the remaining acetic anhydride by the method devised by Orton and M. G. Edwards,[6] and amplified by Orton and Marian Jones.[7] The amount of anhydride found at a given period of the reaction corresponded well with that calculated from the initial concentration on the assumption that the loss of anhydride was solely due to acetylation. The accuracy and the refinements of this method of analysing the system are mainly due to the exhaustive experiments of Mr. W. H. Gray[8] on the stability of nitric acid in acetic acid solution and allied problems. The error in the estimation of the nitroamine in an acetic acid solution is not above $\frac{1}{4}$ per cent., whilst the error in the determination of the aniline by conversion into nitroamine falls below 1 per cent.

The velocity coefficients for a reaction of the second order are remarkably constant, in spite of the complicated and intricate analyses by which they are obtained.

Illustrations of the results are given in the following table:—

Exp. A. Initial concentrations:—*s*-tribromoaniline, 0·04; acetic anhydride $0·04 \times 3·83$; $H_2SO_4 = M/363·8$.

Time from mixing. Min.	Percentage aniline acetylated.	K_{II}.
41	17·52	0·031
86	31·5	0·030
146	48·14	0·031
240	69·92	0·037

Exp. B. *s*-tribromoaniline, 0·02; acetic anhydride, $0·02 \times 7·08$; $H_2SO_4 = M/363·8$.

Min.		
66	38·19	0·053
157	69·65	0·069
283	90·05	0·064

Exp. C. *s*-tribromoaniline, 0·02; acetic anhydride, $0·02 \times 7·08$; $H_2SO_4 = M/727·6$.

Min.		
40	17·25	0·032
87	28·55	0·026
142	40·3	0·025
240	61·3	0·028

Since in the presence of sulphuric acid the anhydride is immediately

[4] *Trans. Chem. Soc.* 1902, **81**, 490.
[5] *Thesis submitted to the University of Wales*, 1914.
[6] *Trans. Chem. Soc.* 1911, **99**, 1181.
[7] *Trans. Chem. Soc.* 1912, **101**, 1716.
[8] *Loc. cit.*, and *Analyst*, 1912, **37**, 303.

hydrolysed by water in the acetic acid medium, the initial concentration was arrived at by deducting an amount equivalent to the water from the anhydride used.

The experiments have led to some very interesting results:—

1. The reaction is of the second order; the value of the expression, $\frac{1}{t} \cdot \frac{x}{(a-x)}$, is approximately halved by doubling the dilution.

2. The speed is approximately proportional to the concentration of the catalyst when the concentrations of the aniline and anhydride are kept constant.

3. A very remarkable effect was produced by variation of the concentration of the aniline, when anhydride and catalyst are kept constant. It would be expected that the speed of acetylation would fall on decreasing the concentration of the aniline; on the contrary, however, the speed increases. A comparison of experiments A and B shows that on halving the concentration of the aniline the speed is roughly doubled. The most obvious explanation of the observation is that the acid catalyst is partly combined with the aniline. Such a balanced action would follow the equation of equilibrium:—

$$[\text{Aniline}]\,[H_2SO_4] = K\,[\text{anilinium salt}].$$
$$[H_2SO_4] = K\,\frac{[\text{anilinium salt}]}{[\text{aniline}]}.$$

Since the proportion of the acid, and therefore of the salt, is very small in comparison with that of the aniline in these systems, the concentration of the acid is roughly inversely proportional to that of the aniline. The concentration of the free acid (or perhaps acid salt) is the dominant factor in the reaction, and hence the effect (if there be one) of the decrease of the aniline is completely concealed. This suggestion is made more probable by the effect of simultaneous reduction of the concentration of both acid and aniline; the velocity of acetylation is scarcely changed (Exp. C). It appears, then, that the speed of acetylation is independent (within certain limits) of the concentrations of the acid and aniline, provided that these quantities remain in the same ratio.

The action of the catalyst probably lies, as has been frequently suggested, in producing an 'active modification' of the acetic anhydride, which alone reacts with the aniline. The evidence, so far as it goes, points to the reaction of the anhydride and catalyst being momentary, whilst that of the 'active' form and the aniline is a time reaction. Too much stress cannot be put upon the fact that the reaction was of the second order, for the excess of anhydride was considerable. The combination of the acid with the aniline, moreover, obscures the issue, and renders a decision difficult with an acid catalyst.

A complete account of this research will be published in one of the usual chemical journals.

The Study of Plant Enzymes, particularly with relation to Oxidation.—Third Report of the Committee, consisting of Mr. A. D. HALL (*Chairman*), Dr. E. F. ARMSTRONG (*Secretary*), Professor H. E. ARMSTRONG, Professor F. KEEBLE, *and* Dr. E. J. RUSSELL.

WORK is being continued along the lines indicated in former reports.

The further investigation of the distribution of oxydases (peroxydase) in the flowers of *Primula sinensis* has led to the discovery that in certain white-flowered races which breed true to whiteness the peroxydase has a definite zonal distribution. Such white-flowered races, when crossed with coloured forms, yield in the F_2 generation a certain number of plants having flowers which exhibit a colour pattern of a similar zonal character. Hence this pattern may be referred to a lack of uniformity in distribution of the peroxydase constituent of the colour-forming mechanism, not of the chromogen. This investigation has involved the study of a large number of plants of known genetic constitution and of their progeny; it may be expected that eventually it will throw light on the phenomena of flaking and colour pattern in flowers.

Concurrently with the study of the distribution of oxydases in plants, the occurrence of reductases has also been investigated, using this term as a general expression for substances which exert a reducing action. After many trials, partial success has been achieved by the discovery of agents indicative of such compounds, and evidence of the zonal distribution of reductases has been obtained.

A general summary of the bearing of chemical observations on genetic constitution and the relation of enzymes to colour inheritance in plants was given before the Linnean Society in March, when it was particularly pointed out that, in life, interaction takes place between substances in pairs, the one being oxidised and the other reduced. Consequently the same interaction is often recorded whether oxydase or reductase be indicated by the agent used. This conception materially simplifies the study of the oxidative changes in plants.

The formation of red pigments from yellow flowers by reduction and subsequent oxidation described in the last report has been further studied during the year. To elucidate the precise nature of the change by working with material of known structure, the experiments were extended to quercetin, which has been reduced under a variety of conditions. As a rule, colourless compounds are formed which become red on exposure to the air or on the addition of hydrogen peroxide. The problem has been investigated independently at Reading by A. E. Everest ('The Production of Anthocyanins and Anthocyanidins,' *Proc. Roy. Society*, 1914, 87 B. 144), who finds that the change from yellow to red may be effected by reduction alone, and that reduction takes place quite readily without the occurrence of hydrolysis. As Willstätter has now directed his attention to the chemical structure of the anthocyanic class of pigments, it is not proposed to continue the research in this direction.

A study has been made of the rate at which various carbohydrate solutions are able to decolourise methylene blue in alkaline solution,

as this method is of value in discriminating between glucose and fructose (compare Muster and Woker, *Pflügers Archiv*, 1913, **155**, 92). On adding a few drops of methylene blue to a freshly prepared solution containing one per cent. of the carbohydrate, together with half of one per cent. of solution of sodium hydroxide, the blue color is almost immediately discharged in presence of fructose, but only after a certain interval—15 minutes—by glucose. After standing, the glucose solution acts much more rapidly, whereas the fructose is less active than at first. Most probably the active agent is the enolic form common to both sugars; as Lobry de Bruyn was the first to show, this is formed from both by the action of alkali. The possibility of the formation of fructose from glucose and *vice versa* in this manner in the plant must not be overlooked. The methylene blue test has been applied to a number of carbohydrates, so as to compare their relative rates of enolisation. Indigo-blue solution, which changes from green to red, and finally to yellow, as it is reduced, is an equally sensitive agent. In all cases, agitation with air restores the colour; the colour is not destroyed in faintly acid solution.

The behaviour of lipase has been further studied during the year. It has been shown that synthesis takes place under the influence of the enzyme to the greatest extent in the absence of all but traces of water, and that the presence of even a small proportion of water greatly favours action in the reverse direction.[1]

In view of the presence of ammonia in the nodular growths appearing on the roots of Leguminosæ, it appeared probable that the enzyme urease would be found in these. It has been detected in the nodules from Lupins and a number of other Leguminosæ. Attempts to detect the enzyme in organisms cultivated from the nodules have thus far been attended with negative results.

Mr. Benjamin, working at the Hawkesbury Agricultural College, near Sydney, Australia, has detected urease in nodules from several Australian plants, including wattles; also on tubercles derived from the Cycad *Macrozamia spiralis*. He has found urease also in the seeds of *Abrus precatorius*.

Correlation of Crystalline Form with Molecular Structure.—Report of the Committee, consisting of Professor W. J. Pope *(Chairman)*, Professor H. E. Armstrong *(Secretary)*, Mr. W. Barlow and Professor W. P. Wynne.

The following communications have been made to the Royal Society during the year:—

Morphological Studies of Benzene Derivatives. V. The Correlation of Crystalline Form with Molecular Structure: A Verification of the Barlow-Pope Conception of Valency-Volume. By Henry E.

[1] *Proc. Roy. Soc.* 1914, Series B, 'Studies on Enzyme Action,' xxii., Lipase (iv.) 'The Correlation of Hydrolytic and Synthetic Activity,' by Henry E. Armstrong and H. W. Gosney.

ARMSTRONG, R. T. COLGATE and E. H. RODD. Proc. Roy. Soc., Series A, Vol. 90, pp. 111-173.

VI. Parasulphonic derivatives of Chloro-, Bromo-, Todo, and Cyanobenzene. By C. S. MUMMERY, B.Sc.

VII. The Correlation of the Forms of Crystals with their Molecular Structure and Orientation in a Magnetic Field in the Case of Hydrated Sulphonates of Dyad Metals. By HENRY E. ARMSTRONG and E. H. RODD.

In the first of these it is shown that the method of treatment introduced by Barlow and Pope is applicable to a large number of derivatives of benzenesulphochloride or bromide of the formula $C_6H_3R_2 \cdot SO_2Cl$, R being an atom of halogen. When equivalence parameters are calculated from the axial ratios and the valency volume, in nearly thirty cases the values found of two of the parameters are all but identical with those of the corresponding parameters of benzene, the third parameter being increased by the same amount beyond the benzene value by the introduction of the sulphonic radicle. Hence it is to be supposed that the halogens have the same relative valency volume as hydrogen in all the compounds considered. Numerous other cases are quoted in support of the conception of valency introduced by Barlow and Pope.

In the second communication data are given for various derivatives of benzenesulphochloride containing but one atom of halogen. It is shown that these fall into line with the di-derivatives.

In the third attention is called to crystallographic peculiarities presented by substituted benzenesulphonates of dyad metals and a close relationship to corresponding toluenemephonates is established. The influence of water of crystallisation is considered.

Attention is specially directed also to the peculiar behaviour of certain isomorphous salts of iron, cobalt and nickel in the magnetic field. When suspended similarly in either of two axial directions, corresponding isomorphous iron and cobalt salts always act along crystallographic axes at right angles to each other. Nickel salts behave like cobalt salts when suspended in the one axial direction, like iron salts when suspended in the other. Apparently the difference in the behaviour of the various salts is to be referred to magnetic peculiarities in the metallic atoms.

Study of Solubility Phenomena.—Interim Report of the Committee, consisting of Professor H. E. ARMSTRONG *(Chairman)*, Dr. J. VARGAS EYRE *(Secretary)*, Dr. E. F. ARMSTRONG, Professor A. FINDLAY, Dr. T. M. LOWRY, *and* Professor W. J. POPE.

MUCH of the time since the appointment of this Committee has been devoted to setting up the required apparatus and getting it into working order in a new laboratory. Materials have been purified and work has been done to ascertain within what limits solubility determinations were trustworthy under the new conditions.

Preliminary trials have been made to ascertain the influence of isomeric alcohols on the solubility of salts in water at 25° C. Small differences have been observed in the precipitating effect of the butylic alcohols, and work is now in progress to determine the variations in solubility of the chlorides of potassium, sodium and ammonium brought about by the addition of small quantities of the isomeric propylic, butylic and amylic alcohols.

It is desired that the Committee be reappointed.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Mr. R. H. TIDDEMAN (*Chairman*), Dr. A. R. DWERRYHOUSE (*Secretary*), Dr. T. G. BONNEY, Mr. F. W. HARMER, Rev. S. N. HARRISON, Dr. J. HORNE, Mr. W. LOWER CARTER, Professor J. W. SOLLAS, *and* Messrs. W. HILL, J. W. STATHER, *and* J. H. MILTON.

THE Committee reports that owing, probably, to the early date of the meeting no lists of erratics have been contributed during the year, and in consequence no part of the grant has been expended.

The Committee seeks reappointment with a grant of 5*l*.

The Preparation of a List of Characteristic Fossils.—Second Interim Report of the Committee, consisting of Professor P. F. KENDALL (*Chairman*), Mr. W. LOWER CARTER (*Secretary*), Mr. H. A. ALLEN, Professor W. S. BOULTON, Professor G. COLE, Dr. A. R. DWERRYHOUSE, Professors J. W. GREGORY, Sir T. H. HOLLAND, G. A. LEBOUR, *and* S. H. REYNOLDS, Dr. MARIE C. STOPES, Mr. COSMO JOHNS, Dr. J. E. MARR, Dr. A. VAUGHAN, Professor W. W. WATTS, Mr. H. WOODS, *and* Dr. A. SMITH WOODWARD, *appointed for the consideration thereof.*

No meeting of the Committee was held during the year, but numerous suggestions for a list of fossils were received. From these a provisional list was compiled by the Secretary, and uncorrected were printed and circulated. This provisional list, when revised, will, it is hoped, form the basis for the publication of an amended list of fossils next year. The Committee ask for reappointment with a grant of £10.

Geology of Ramsey Island, Pembrokeshire.—Final Report of the Committee, consisting of Dr. A. STRAHAN (*Chairman*), Dr. HERBERT H. THOMAS (*Secretary*), Mr. E. E. L. DIXON, Dr. J. W. EVANS, Mr. J. F. N. GREEN *and* Professor O. T. JONES.

THE Committee have to report that the grant made to them in 1913 to aid Mr. J. Pringle in continuing his researches in the west of Pembroke-

shire has been spent. They have also to report that the detailed mapping of the island has been completed. The examination of the rocks and fossils which have been collected will be proceeded with.

For the purpose of description the island can be divided conveniently into two areas—a northern area composed of Lingula Flags, Arenig mudstones and shales, Lower Llanvirn, and the intrusive mass of Carn Ysgubor; and a southern area of Lower Llanvirn shales with inter-bedded tuffs and rhyolites, and a thick mass of intrusive quartz-porphyry. To the latter area belongs the mass of rhyolitic and brecciated tuffs of Carn Llundain.

Northern Area.

Lingula Flags.—The Lingula Flags consist of bluish-grey flaggy, micaceous shales with ribs of hard grey close-grained sandstone, some of which reach a thickness of two feet. They occupy the headland of Trwyn Drain-du, and they extend eastwards to Bay Ogof Hên, while on the eastern side of the island they form the cliffs from the north-east corner to Road Uchaf. The Flags also occur in the headland to the south of Abermawr. They are highly fossiliferous, and yield *Lingulella davisi* in great abundance.

Arenig.—All the zones of the Arenig are present. The lowest beds are bluish-grey sandy mudstones and shales with *Ogygia selwyni, Orthis proava*, and *O. menapiæ*. They are confined to the north-east corner of the island, and are faulted against the Lingula Flags. The mudstones are followed by bluish-black shales belonging to the Extensus Zone, and are well displayed in the cliffs at Road Uchaf and Road Isaf. Similar shales belonging to the Hirundo Zone are present in Abermawr.

Lower Llanvirn.—The base of the Lower Llanvirn is seen only in the cliffs in Abermawr, where the shales of the Hirundo Zone are succeeded by a thick series of hard dark- and light-coloured tuffs of fine texture, which yield *Didymograptus bifidus* in their highest beds. The tuffs are followed by fossiliferous blue-black shales, but their full thickness is not seen in the northern area.

Intrusive Rocks.—Carn Ysgubor is formed of an intrusive mass of quartz-albite-diabase, which has invaded the sediments of Lower Llanvirn, Arenig, and Lingula Flags. A small intrusion occurs south of Abermawr, where Lingula Flags are in contact with a quartz-keratophyre.

Southern Area.

This area was described in the first report, in which it was shown to be composed of *D. bifidus* shales which had been invaded by a thick mass of quartz-porphyry. The shales, well displayed in the cliffs of Porth Llauog and Foel Fawr, are highly fossiliferous, and a large collection of graptolites has been made from them. They contain layers of coarse agglomeratic tuff, and at Foel Fawr pass upwards into thick beds of tuff which are conformably overlain by grey rhyolites. The tuffs and conglomerate on Carn Llundain belong to the same period of eruption.

The two points of interest, therefore, which were made the object of mapping the island have been successfully solved. It has been found that the so-called Tremadoc beds are Arenig sediments, and that they do not pass downwards into the Lingula Flags, but are brought against them by a fault; also that the rocks hitherto regarded as pre-Cambrian belong to a period of igneous activity that occurred in Lower Llanvirn, or even later, times.

It is hoped that the full description of the district will be completed this year, and it is the present intention of Mr. J. Pringle to communicate the results of his investigations to the Geological Society of London.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—Interim Report of Committee, consisting of Professor GRENVILLE COLE *(Chairman)*, Professor T. JOHNSON *(Secretary)*, Dr. J. W. EVANS, Dr. R. KIDSTON, *and* Dr. A. SMITH WOODWARD.

OWING to the early date at which this year's Report is required, and the absence of Professor Johnson at the Australian Meeting, it is impossible to utilise the funds available for field-work, which normally is carried on during the long vacation.

Your Committee asks for its reappointment, and for the renewal of the grant of 10*l*. not utilised in 1913-14, together with the unexpended balance of 9*l*. odd.

Two papers have been published during the past year:—T. Johnson: 1. *Ginkgophyllum Kiltorkense* sp. nov.; 2. *Bothrodendron Kiltorkense* Haught. sp., its Stigmaria and Cone (' Sci. Proc., R. Dublin Society,' vol. xiv.).

Stratigraphical Names.—Interim Report of the Committee, consisting of Dr. J. E. MARR *(Chairman)*, Professor GRENVILLE COLE, Mr. BERNARD HOBSON, Dr. J. HORNE, Professor LEBOUR, Dr. A. STRAHAN, Professor W. W. WATTS, *and* Dr. F. A. BATHER *(Secretary), appointed to consider the preparation of a List of Stratigraphical Names used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.*

AT its Meeting in Stockholm, 1910, the International Geological Congress appointed a Committee to produce a 'Lexique international de Stratigraphie.' The convener of this International Committee is Dr. Lukas Waagen, of Vienna, and the Secretary of the present Committee had the honour of being appointed representative of Great Britain.

Before the Meeting of the International Geological Congress in Toronto, 1913, various proposals were discussed by the members of

the International Committee, and a provisional Report was laid before the International Congress. Unfortunately neither Dr. Waagen nor Dr. Bather were able to attend the Congress in Toronto, and up to the date of writing they have received no official communication from the officers of the Congress. It is, however, understood that the Congress can grant no subvention to aid the work.

The situation, therefore, may be thus summarised:—The International Congress has appointed a Committee to produce a laborious and costly work of undoubted value to all interested in Geology and the allied sciences. There are no funds for this purpose. The details of the scheme, even if decided on at the Congress, are not yet known to the present Committee of the Association.

Consequently your Committee has been unable to take any steps, although some of its members have made note of stratigraphical names observed in the course of their ordinary work, and are prepared to continue this practice and eventually to place such material at the disposal of the International Committee. Your Committee is, however, well aware that the search for names must be conducted systematically, and it considers that funds will be needed to pay searchers and compilers. A grant is not asked for at present, merely because it is not yet possible to draw up a plan of operations.

The fact that this Report will be presented to the Association when meeting in Australia leads your Committee to point out that it has been appointed to consider names used in the British Isles, and that no provision has yet been made for the other constituents of the British Empire. As regards India, indeed, the work has been accomplished by Sir Thomas Holland and Mr. G. H. Tipper in their 'Indian Geological Terminology.'[1] But it is desirable that other Committees should be formed, and the present occasion seems appropriate for the establishment of one to deal with Australasia. Any such Committees would communicate directly with Dr. L. Waagen (K.k. geolog. Reichsanstalt, Wien).

Your Committee asks for its reappointment, for the present without a grant.

Fauna and Flora of the Trias of the Western Midlands.—Report of the Committee, consisting of Mr. G. Barrow *(Chairman),* Mr. L. J. Wills *(Secretary),* Dr. J. Humphreys, Mr. W. Campbell Smith, Mr. D. M. S. Watson, *and* Prof. W. W. Watts.

This Committee regrets that owing to the early date at which the report has to be submitted this year, very slight progress has been made with the digging operations in Warwickshire and Worcestershire. Some hundred and more specimens have been obtained from the Arden Sandstone at Shelfield, near Alcester, and Hunt End, near

[1] *Mem. Geol. Surv. India,* vol xliii., Part 1, 1913.

Redditch, including the bones and teeth of *Labyrinthodon*, teeth of *Polyacrodus* and *Phœbodus* (?), plant remains, &c.

Permission has already been obtained to work in the famous Coton End Quarry at Warwick, and arrangements made for further digging at Shelfield should the grant be renewed. It is felt that the chief difficulty is the discovery of productive fossiliferous horizons, and then the arrangement for labour in scattered and often secluded localities. The larger part of the money so far spent has been in travelling expenses in this connection.

The Lower Palæozoic Rocks of England and Wales.—Report of the Committee, consisting of Prof. W. W. WATTS (*Chairman*), Prof. W. G. FEARNSIDES (*Secretary*), Prof. W. S. BOULTON, Mr. E. S. COBBOLD, Mr. V. C. ILLING, Dr. C. LAPWORTH, *and* Dr. J. E. MARR, *appointed to excavate Critical Sections therein.*

Nuneaton Area.—Mr. V. C. Illing reports that during the winter of 1913-14 and the ensuing spring, systematic trenching was begun across the outcrop of the Abbey Shale division of the Stockingford Shales. By the kind permission of Mr. Phillips, of Ansley Hall, the work was carried out in the Hartshill Hayes. A trench, thirty yards long, two feet wide, and three feet deep, was made in the direction of the dip of the shales, and cross trenches were cut along the strike of nine of the beds richest in fossils. In some cases these latter trenches were cut to a depth of ten feet. About thirty yards away, in the direction of the strike, a second trench was cut across the outcrop, and, in addition to the discovery of further types of fossils, evidence was obtained of lateral changes in lithology. Some five thousand specimens were obtained, chiefly of trilobites, ranging over some fifty different species. These indicate a fauna corresponding to that of the Upper Solva Beds and the Lower and Middle Menevian Beds, *i.e.* the zones of *Conocoryphe exsulans*, *Agnostus parvifrons*, *Conocoryphe æqualis* (?), and *Paradoxides davidis*, of Sweden, and the zones of *P. aurora*, *P. hicksii*, and *P. davidis*, of South Wales. In addition new links have been found between the fauna of this area and that of the corresponding beds in Bohemia, three of the forms being new to Britain. The fossils are being described and photographed, and a paper on the subject will be presented to the Geological Society.

Comley Area, Shropshire.—Mr. E. S. Cobbold reports that excavations have been begun in the Cambrian Rocks of the Comley area, but no report of the results is yet possible.

The Committee asks for reappointment with a grant of 15*l.*, which would include the unspent portion of this year's grant.

The Upper Old Red Sandstone of Dura Den.—Report of the Committee, consisting of Dr. J. HORNE *(Chairman)*, Dr. T. J. JEHU *(Secretary)*, Mr. H. BOLTON, Mr. A. W. R. DON, Dr. J. S. FLETT, Dr. B. N. PEACH, *and* Dr. A. SMITH WOODWARD, *appointed to conduct the further exploration thereof; with a separate report by* Dr. SMITH WOODWARD *on the Fish Remains.*

SINCE the preliminary report was presented at the Birmingham Meeting the excavations for fossil fishes at Dura Den have been completed and the ground has been levelled. The Committee desire again to acknowledge the courtesy of Mr. Bayne-Meldrum, of Balmungo, the proprietor, who gave great facilities for carrying out the operations. They wish also to express their obligations to Mr. R. Dunlop, from Dunfermline, who superintended the work on the spot and who took a series of excellent photographs of the best specimens of fossil fishes.

At the outset brief reference may be made to the geological structure of the ground near Dura Den. Strata of Upper Old Red Sandstone age underlie the long depression of the Howe of Fife, which ranges westwards from St. Andrews Bay, between the slopes of the Ochil Hills on the north and the heights of the Carboniferous rocks with their intrusive masses on the south. The actual junction with the Lower Old Red Sandstone volcanic series of the Ochils is hidden everywhere by drift, but the line of contact is evidently an unconformable one. For the sheets of andesite dip south-east at angles of about 15°, and are overlapped at different horizons by the more gently inclined members of the Upper Old Red Sandstone.

In Central Fife there is a conformable passage from the Upper Old Red Sandstone into the Lower Carboniferous strata. But in Eastern Fife the top of the Upper Old Red Sandstone is cut off by a fault which crosses Dura Den in a north-easterly direction and brings down the Carboniferous strata on the south-east side.

The ravine of Dura Den has been cut by the Ceres Burn since the Ice Age. This rivulet is formed by the union of a number of smaller streams which rise in the Carboniferous area of Fife. The Den has been excavated across the line of fracture and is about a mile and a half in length (see Fig. 1).

Below the mouth of the Den the Ceres Burn enters the alluvial plain of the Eden and joins that river about a mile above the village of Dairsie. Dura Den is eroded in the Lower Carboniferous and Upper Old Red Sandstone formations. For a distance of several hundred yards the Upper Old Red Sandstone strata are laid bare in the channel of the stream and in a range of picturesque cliffs on either side. The section runs along the strike of nearly horizontal beds, so that only a comparatively small thickness of rocks is exposed. These belong to the upper part of the formation, but the actual top, as already

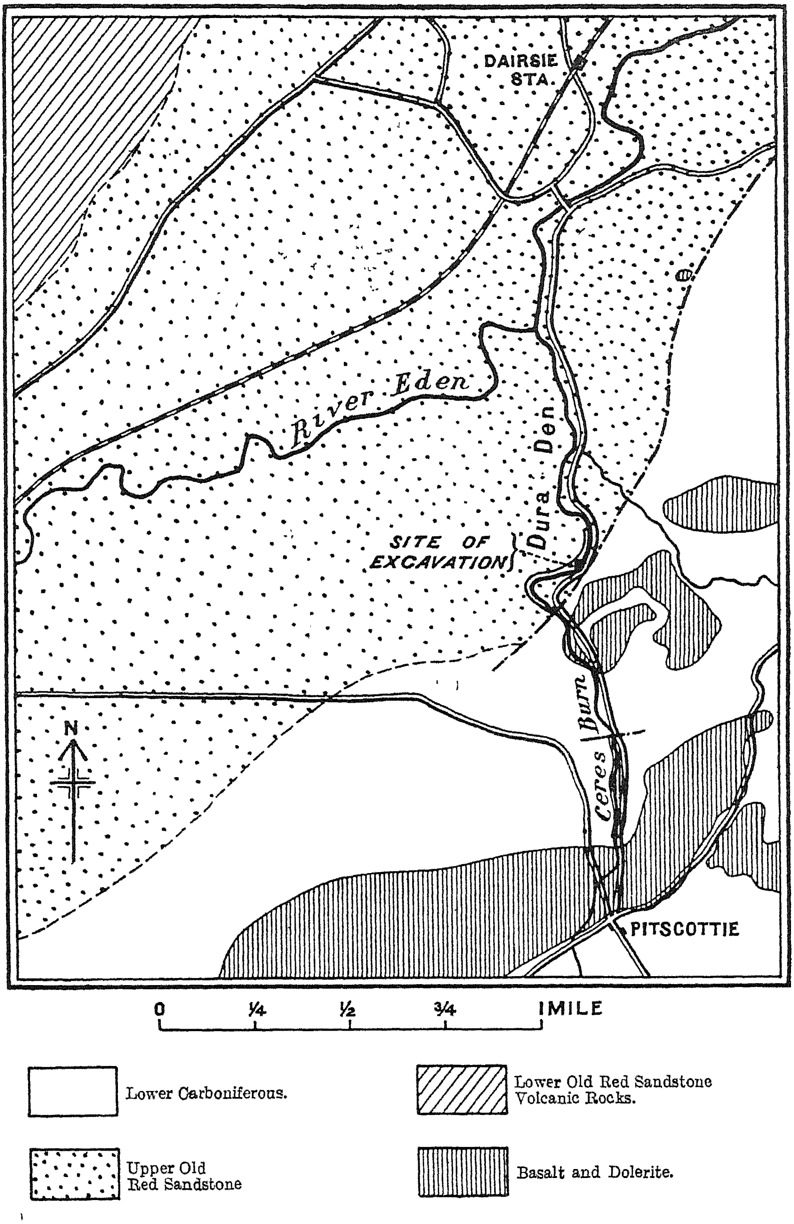


FIG. 1.—Geological Sketch-map of the District surrounding Dura Den.

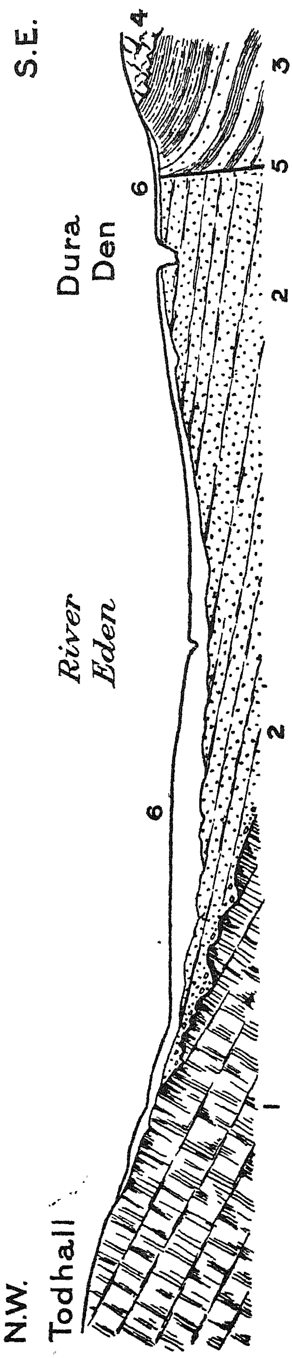


FIG. 2.—Section across the valley of the Eden from Todhall to Dura Den showing the relations of the strata (after Sir A. Geikie).

1. Volcanic Series of Lower Old Red Sandstone.
2. Red and Yellow Sandstones and Conglomerate of Upper Old Red Sandstone age.
3. Lower Carboniferous Series. 4. Intrusive Dolerite. 5. Fault. 6. Superficial Deposits.

indicated, is cut off by the fault, near which the Lower Carboniferous strata are seen dipping at angles of 35° to 40° to the south-east. The rocks consist of yellow, red, and greenish sandstones, with bands of clay or marl, and are nearly horizontal. They are rather fine-grained, somewhat fissile, and, in places, extremely false-bedded.

Remains of fishes in the Upper Old Red Sandstone of Fife were first observed in 1831 at Drumdryan, near Cupar, by the Rev. John Fleming. The scales detected by him were found to occur more abundantly at Dura Den, a mile farther east, and entire fishes were obtained there, preserved in the sandstone.

For years the Rev. Dr. Anderson worked at these beds and published numerous papers descriptive of the region. The fish-remains obtained from time to time at this famous locality were examined and described by Agassiz, Huxley, and other investigators. The excavations were carried on partly under the guidance of a Committee of the British Association, which gave its first report in 1860.

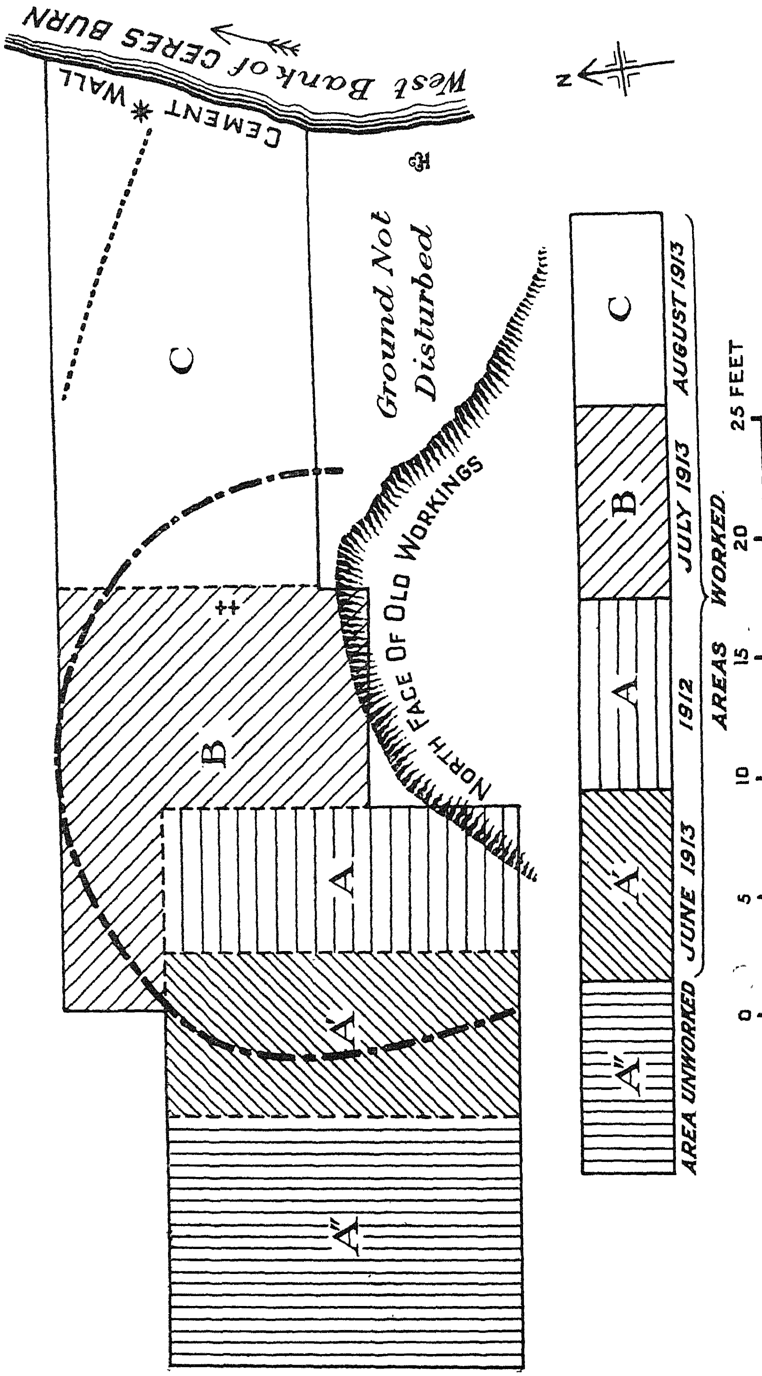
The remains occur as carbonised impressions on the fine-grained pale-yellow stone, and sometimes are to be found crowded together. Sir A. Geikie has remarked that 'the Dura Den sandstone does not so much mark a definite palæontological subdivision as an exceptional area where the organisms were rapidly killed and buried in great numbers.'[1]

On the other hand, Dr. Traquair correlated the Dura Den fish fauna with that of the highest subdivision of the Upper Old Red Sandstone on the south side of the Moray Firth. Dr. Traquair's list of fishes found at Dura Den during the earlier excavations is given below:[2]

Bothriolepis hydrophila, Ag.
Phyllolepis concentrica, Ag.
Glyptopomus minor, Ag.
Glyptopomus kinnairdi, Huxl.
Gyroptychius heddlei, Traq.
Holoptychius flemingi, Ag.
Phaneropleuron andersoni, Huxl.

In the spring of 1912 the Dundee local Committee of the British Association began excavations with the view of re-exposing the fish-bed at Dura Den. The work was carried on under the supervision of Mr. A. W. R. Don. The exact site of the previous diggings was unknown, but, according to local tradition, many of the first specimens had been obtained from the sandstone forming the bed of the stream and from an excavation on the left side between the stream and the mill-lade. After some trial explorations the fish-bed was eventually struck, and part of the old workings was exposed. The latter lay 30 feet to the west of the stream, just opposite the north end of the garden belonging to the house known as 'The Laurels,' now in the occupation of Dr. Graham Campbell. A pit was opened from the base of the old workings in the direction of the mill-lade, and the fish-bed was found to lie at a depth of nine feet from the surface. Only a small

[1] 'The Geology of Eastern Fife' (*Mem. Geol. Surv.*), 1902, p 59.
[2] 'The Geology of Eastern Fife' (*Mem. Geol. Surv.*), 1902, p. 58.



— — — Outer limit of rich fish-bearing zone. ---------- Sandstone layer with fragmentary fish remains.

* Locality of specimen containing *Phyllolepis* and *Bothriolepis*. ‡ Locality of specimen containing *Bothriolepis*.

FIG. 3.—Ground-plan showing areas excavated in 1912 and 1913, and north face of Old Workings at Dura Den.

part of the fish-bed was then worked. A few good specimens were obtained, and were on view when the locality was visited during one of the excursions arranged in connection with the Geological Section of the British Association Meeting at Dundee in 1912.

Work was resumed by our Committee on May 5, 1913, and proceeded more or less continuously to the end of August 1913. The pit, opened in 1912, having been partly refilled, had to be cleared again. As stated in the preliminary report issued last year, a definite plan was followed in the excavations. The fish-bearing zone was uncovered and removed in successive sections (fig. 3).

The sandstone layer, rich in fish-remains, is restricted to a zone about two inches thick. It lies at an average depth of nine feet from the surface, and is overlain by about four feet of comparatively barren sandstone, capped by about four feet of loose superficial materials. It was decided to work the fish-bed in the direction in which the fish-remains appeared to be most abundant. As the operations extended towards the mill-lade in the area marked A′ in fig. 3, the sandstone did not yield fishes, as if the limit of the rich fish-bearing zone had been reached in that direction. The arrangement was then made to carry on the excavations towards the stream and just north of the face of the old workings.

The finest specimens of fossil fishes and the largest number were obtained in the middle section (area marked B in fig. 3) and in the immediately adjoining parts of the other two sections (A and C in fig. 3). The greater part of the area marked C in fig. 3 proved to be somewhat disappointing, though one slab containing twenty specimens was found there and a fine example of *Phyllolepis* quite close to the stream. Good specimens, however, were scarce in section C outside the limit of the rich fish-bearing zone. In the north-east corner of it near the stream a sandstone layer with fragmentary fish-remains was traced for a short distance.

It is worthy of note that large scales of *Holoptychius* were obtained in the sandstone three feet above the fish-bed, and that fish-scales in a fragmentary condition were found scattered throughout the sandstones above that zone. No fish-scales were detected below that horizon, although the excavations were continued downwards for nearly two feet beneath that zone.

Fine examples of sun-cracks were seen in the sandstone at depths varying from two to four inches below the fish-bed, and, at one locality, one inch above that horizon. This feature is suggestive, and probably points to desiccation as a cause of the death of the fishes in a shoal at this locality.

In all forty-two slabs of stone with well-preserved fish-remains were obtained. These were photographed by Mr. Dunlop, and the photographs were sent to Dr. Smith Woodward for determination. About fifty fragmentary specimens were collected which were not photographed. The whole collection has been stored in an adjoining mill under lock and key.

The expenses connected with these detailed investigations have exceeded the British Association grant of 75*l.* and the contribution of

12*l*. from Mr. Bolton of the Bristol Museum. The Curator of Ichthyology in the American Museum of Natural History, New York, has offered a donation towards the expenses on condition that some of the specimens be given to that Museum. The Committee have accepted this offer.

On June 19 the Chairman, the Secretary, Dr. Smith Woodward, and Mr. Dunlop visited Dura Den. Each specimen was then examined by Dr. Smith Woodward, and a scheme of distributing the fish-remains to various public institutions was adopted by the members of the Committee who were then present. The distribution will be carried out during this summer.

The report of Dr. Smith Woodward is appended:

Preliminary Report on the Fossil Fishes from Dura Den.
By Dr. A. SMITH WOODWARD.

The very large majority of the fishes found during the excavations at Dura Den are examples of *Holoptychius flemingi*, and most of the slabs exhibit no other species. Specimens of *Glyptopomus kinnairdi*, *Glyptopomus minor*, *Phaneropleuron andersoni*, and *Bothriolepis hydrophila* occur but rarely. All are nearly complete, as usual, having been suddenly buried; and it is probable that when studied in detail the new collection will make some small additions to our knowledge of the species represented.

The only important novelty is a nearly complete specimen of *Phyllolepis*, which shows for the first time the arrangement of the dermal plates in this rare fish, and apparently determines its affinities. The genus has already been recorded from Dura Den,[3] but it is known only by detached plates. The armoured portion of the fish is oval in shape and depressed, so that the fossil is exposed from above or below. The surface shown is covered chiefly with two large plates, one behind the other, each irregularly hexagonal in shape and slightly broader than long. The anterior plate is somewhat the smaller and narrower, and the regularity of its concentric ridge-ornament is interrupted by waviness in lines apparently of slime-canals which radiate symmetrically from the centre to the periphery. The posterior plate is ornamented exactly like the imperfect typical plate of *Phyllolepis concentrica* from Clashbennie.[4] Round the anterior plate are arranged four pairs of small plates, which decrease in width forwards. Their ridge-ornament is peculiar in being concentric only with two or three of the margins of each plate and running out at right-angles to the inner margin. The postero-lateral plate is long and narrow and much the largest, extending along the posterior two-thirds of the anterior median plate. The next plate forwards, also long and narrow, is much less than half as large as the postero-lateral just described, and the two pairs of anterior plates are comparatively small. This series of plates on each side is continued behind by another still larger plate, which flanks somewhat less than the anterior half of the posterior median plate and ends postero-laterally in a produced angle or cornu.

[3] A. S. Woodward, *Catal. Foss. Fishes Brit. Mus.*, Pt. II. (1891), p. 314.
[4] L. Agassiz, *Poiss. Foss. Vieux Grès Rouge* (1844), p. 67, pl. xxiv. fig. 1.

FIG. 4.—*Phyllolepis concentrica*, Ag.; ventral or dorsal aspect of dermal armour, showing arrangement of plates, two-thirds natural size.

Illustrating the Report on the Upper Old Red Sandstone of Dura Den.

[*To face page* 122.

The ornamental ridges here radiate chiefly from the posterior cornu and the outer margin and are most widely spaced on the postero-internal part of the plate. No vacuities are observable in any of the plates, but all of the anterior pairs are crossed by slime-canals in continuation of the radiating canals on the anterior median plate. The total length of the fossil is 12.5 cm.

The ornamentation of the posterior median plate of the specimen just described seems to justify its reference to the typical species, *Phyllolepis concentrica*, already known by imperfect plates from Clashbennie, Perthshire. It is also interesting to add that some of the other plates agree well with specimens found in association with *P. concentrica* in the Upper Devonian of Belgium.[5] The ornament of the anterior median plate corresponds with that of the so-called *P. corneti*,[6] while both the ornament and shape of some of the lateral plates are essentially the same as those of the small plates named *Pentagonolepis*.[7] The plates forming the lateral cornua do not appear to have been previously seen.

The whole fossil is most suggestive of the ventral aspect of the curious Devonian Ostracoderms *Drepanaspis*[8] and *Psammosteus*.[9] It agrees with *Drepanaspis* in showing two principal median plates one behind the other, though in *Phyllolepis* they are more nearly equal in size. It corresponds with *Psammosteus* in exhibiting a prominent pair of lateral cornua at the hinder end of the series of small marginal plates, opposite the middle of the posterior median plate. It differs from both in lacking separate small tessellated plates. There is, therefore, not much doubt that *Phyllolepis* is a genus of Ostracoderms most nearly allied to the Drepanaspidæ or Psammosteidæ.

Antarctic Whaling Industry.—Report of the Committee, consisting of Dr. S. F. HARMER (*Chairman*), Dr. W. T. CALMAN (*Secretary*), Dr. F. A. BATHER, Dr. W. S. BRUCE, *and* Dr. P. CHALMERS MITCHELL, *appointed to provide assistance for Major G. E. H. Barrett-Hamilton's Expedition to South Georgia to investigate the position of the Antarctic Whaling Industry.*

BY kind permission of the Trustees of the British Museum the Committee arranged for Mr. P. Stammwitz, a taxidermist employed at the Natural History Museum, South Kensington, to accompany Major Barrett-Hamilton to South Georgia; and the greater part of the grant

[5] M. Lohest, 'Recherches sur les Poissons des Terrains Paléozoïques de Belgique,' *Ann. Soc. Géol. Belg.*, vol. xv. (1888), *Mém.*, pp. 155-167, pls. x., xi.

[6] M. Lohest, *loc. cit.*, p. 157, pl. x. fig. 6.

[7] M. Lohest, *loc. cit.*, p. 161, pl. xi. figs. 1-8.

[8] R. H. Traquair, 'Additional Note on *Drepanaspis Gemündenensis*. Schlüter,' *Geol. Mag.* [4] vol. ix. (1902), pp. 289-291.

[9] A. S. Woodward, 'On the Upper Devonian Ostracoderm, *Psammosteus taylori*,' *Ann. Mag. Nat. Hist.* [8] vol. viii. (1911), pp. 649-652, pl. ix.

placed at the disposal of the Committee has been expended in paying his salary and in making certain preliminary payments. He sailed with Major Barrett-Hamilton on October 6, 1913, and work was commenced at South Georgia immediately after their arrival on November 10.

Early in the new year news was received that Major Barrett-Hamilton had died suddenly at South Georgia on January 17, while his inquiries were in full progress. This unlooked-for event, which the Committee record with profound sorrow, naturally altered the entire prospects of the expedition. Mr. Stammwitz had no alternative but to return at once, and after making arrangements for the despatch of the specimens which had been collected, he took the first opportunity of leaving South Georgia, bringing with him the notebooks containing Major Barrett-Hamilton's observations. At the request of the Colonial Office, and with the approval of the Trustees of the British Museum, these notebooks have been placed in the hands of Mr. Martin A. C. Hinton for examination. It is hoped that the results of the work which Major Barrett-Hamilton had done before his death will thus not be entirely lost. The collections brought home comprise a very valuable series of specimens—in particular, flippers, complete sets of baleen, and other anatomical material from the blue whale, the common rorqual, and the humpback whale. These specimens have been presented to the Natural History Museum by Messrs. Chr. Salvesen & Co., at whose whaling station they were obtained, and they should be of service in helping to decide the much-debated question whether these Antarctic whales are specifically identical with their northern representatives.

A few birds were obtained at South Trinidad on the outward journey, and a certain amount of dredging and shore-collecting was done at South Georgia. The collection made includes marine invertebrates and fishes, bird-skins, plants, and a few insects and rock-specimens. These have been handed over to the Natural History Museum, where arrangements are being made to have them determined, and if necessary reported on, by specialists.

At the request of the Meteorological Office, Mr. Stammwitz took a series of observations on sea-temperatures and ice-drift while at South Georgia, and these are now being utilised by the Office.

The Committee wish to record their appreciation of the value of the assistance which was given to the expedition by Mr. J. Innes Wilson, Stipendiary Magistrate of South Georgia, Messrs. Chr. Salvesen & Co., and Mr. Henriksen, the manager of their Leith Harbour Whaling Station, Messrs. Bryde & Dahl, the Tönsberg Whaling Company, and other individuals and whaling companies connected with South Georgia.

The amount actually expended is less by 15*l.* than the total (90*l.*) allotted to the Committee, and it is not proposed to apply for this balance.

Belmullet Whaling Station.—Report of the Committee, consisting of Dr. A. E. SHIPLEY (*Chairman*), Professor J. STANLEY GARDINER (*Secretary*), Professor W. A. HERDMAN, Rev. W. SPOTSWOOD GREEN, Mr. E. S. GOODRICH, Professor H. W. MARETT TIMS, *and* Mr. R. M. BARRINGTON, *appointed to investigate the Biological Problems incidental to the Belmullet Whaling Station.*

THE Committee acting through Professor Herdman arranged with Mr. J. Erik Hamilton and Mr. R. J. Daniel, two post-graduate research students of the University of Liverpool, for the prosecution of their researches in 1913. They proceeded to Belmullet on June 25 and Mr. Hamilton remained until the end of the fishery. Mr. Daniel retired from the investigations on August 26, having been appointed to a post under the Board of Agriculture and Fisheries. Mr. Hamilton's Report is appended.

The Committee desire to express their thanks to Mr. R. M. Barrington for considerable financial assistance. They have been enabled owing to his generosity to arrange with Mr. Hamilton for the further prosecution of the work in 1914. They have now experience with three investigators—Mr. Lillie, Mr. Burfield, and Mr. Hamilton—and they find that the annual expense is about 45*l*. They attach great importance, both from the scientific and economic sides, to the further continuation of these investigations, and beg to apply for reappointment with a grant of 45*l*. for the summer of 1915.

Report to the Committee by J. ERIK HAMILTON, *B.Sc.*

I.—*Introduction.*

In June 1913 Mr. R. J. Daniel and I proceeded to the Blacksod Bay Whaling Station on Ardelly Point, Blacksod Bay, Co. Mayo, Ireland, to continue the work carried on by Mr. S. T. Burfield, B.A., in 1911.[1]

The flensing plane was clearly visible by telescope from the hotel, and the whaling steamers are compelled to pass the Point whenever they come in. In consequence no whale escaped notice, as might otherwise have happened on account of the distance from the Station.

Our first whale was examined on the morning after our arrival, *i.e.*, on June 26, the last on September 9. As Mr. Daniel was appointed to a post under the Board of Agriculture and Fisheries, he had to leave Blacksod on August 26 for his new duties. Consequently the working up of the collections and the preparation of this Report have been left in my hands.

I desire to express my heartiest thanks to Professor W. A. Herdman,

[1] *British Association Report*, 1912, p. 145.

F.R.S., who has given advice and help of great value during the time which was spent in his Laboratory in working up the materials obtained.

To Captain Lorens Bruun and Mr. D. Bingham sincere thanks are due from Mr. Daniel and myself for the way in which they assisted us at the Station. We would also wish to mention that on many occasions the men employed at the Station helped us in the most obliging manner.

Two steamers continue to be used, both fitted with wireless telegraphy, which is employed solely for communication between the boats. As a result of the possession of this apparatus, if one boat finds whales in numbers too great to be dealt with unaided, the other steamer may be called up to assist in making the most of a fortunate find.

Burfield[2] has stated the disadvantages of work at a commercial factory, and I wish to lay particular emphasis on the rarity with which really fresh whales are brought in. It is exceptional for a whale to be anything other than decomposing. Even in those sufficiently fresh to be fit for food the carcase is quite hot in the deeper parts owing to decomposition, while in the other cases carcases lying on the flensing plane fizzle and splutter wherever a cut in the blubber permits the internal gases to blow off.

Sperm Whales are particularly obnoxious, as they are brought from considerable distances. They are frequently caught at Rockall, 240 miles away, and they smell strongly of cuttlefish. In two Sperm Whales which we saw part of the intestine was blown out through the back of the animal by pressure of gases produced by decomposition, and from one specimen a great spout of blood and oil was projected with considerable force over one of the investigators.

About thirty-eight Irishmen and fifteen Norwegians are employed when work is in full swing. Of the Irishmen one is timekeeper and another is second flenser, but all the other skilled workmen are Norwegians.

The 1913 season was the best which the Blacksod Bay Whaling Company has had up to the present. Sixty-four whales were brought in. The whalemen state from their experience that in fine, calm weather the whales go far out for food, and it is the case that during the splendid weather of August very few were taken. But the largest number of whales for a given number of days was brought in between August 27 and September 9, when the weather was still fairly fine. Nearly three thousand barrels of oil were shipped to Glasgow, to which port all the produce of this Station is sent. There were also manufactured about fifteen hundred bags of guano.

All whale oils at present average 20*l.* per ton (=5⅓ barrels), sperm oil and spermaceti having fallen considerably since 1911. The oil is used for the manufacture of explosives, soap, &c., with the exception of the two sperm products. The oil of the Sperm Whale is used for lubrication only, while spermaceti is largely utilised in the manufacture of church candles.

Whalebone from *Balænoptera musculus* and *B. sibbaldii* is now 65*l.* per ton. The baleen of *Megaptera* is of very inferior quality,

[2] *Op. cit.*, p. 146.

while *B. borealis* yields whalebone of considerably greater value, although, since this is a small species, the plates are not of great length.

The flesh of *B. sibbaldii* has an excellent flavour even when taken from a large specimen. As it is full of oil it must be soaked in salt water and vinegar for several hours before being used. If this precaution is observed, it is almost impossible to distinguish whale-meat from good quality of beef-steak. The flesh for food is generally cut from the lateral post-anal region. On the Japanese Stations the entire carcases of the whales taken are, or used to be, sold on the market for food, it being more profitable to dispose of the animals in this manner than to boil them down for oil and guano. In Norway also a considerable amount of whale-meat is utilised by butchers. It is usually salted as soon as the whales are flensed, and is seldom placed on the market in the fresh condition. On account of the extreme rapidity with which whales decompose very few of the Blacksod Company's whales could be used as food.

The attempts to recover the glue from the water resulting from the various cooking processes applied to blubber, meat, &c., have failed. The reason for the failure lies in the amount of steam which is required to evaporate down the solution. This steam consumption necessitates the use of so much coal that the expenditure is not covered by the price received for the glue which results from the process of evaporation.

In whale-hunting the shot which is generally attempted is aimed at a point behind the pectoral fin, as the animal here presents a large target, and the cast-iron harpoon head, with its charge of blasting-powder, is most likely to prove fatal when exploded in the thoracic cavity. The shot, as a matter of fact, which explodes beside the vertebral column in an anterior position is the most fatal. When this happens the whale dies instantaneously. On the other hand, the harpoon may fail to explode. In this case nothing can be done at the moment except to let the harpoon line run out. The whale may rush along the surface or descend almost vertically. If a surface run is made the engines are put at full speed ahead in order to avoid straining the harpoon rope, which is three-inch manilla cable. When the whale dives down there is serious risk of the rope snapping. One such case occurred to our knowledge during the 1913 season. Only a few fathoms of cable were lost on this occasion, but at other times whales have been known to take out the whole of the three or four hundred fathoms attached to the harpoon, and then to break the line at the bow of the boat. The whale is very much exhausted after a deep dive such as this, and when it returns to the surface another harpoon is fired into it, which almost invariably proves fatal. Even if the rope is broken the animal is usually so fatigued that it is readily approached and secured. We were informed by a very experienced Norwegian whaler that it has happened that a steamer, having become fast to a wounded whale, has 'played' it for as much as thirty hours before the *coup de grâce* could be delivered.

II.—*Numbers and Species taken at the Blacksod Bay Station in* 1913.

The number of whales taken in the 1913 season was sixty-four, as has been stated. Of these fifteen were brought in previous to our arrival; we therefore examined forty-nine. Five species came under our notice, in the following numbers:—

Finners (*Balænoptera musculus*, L.)	37
Blue Whales (*B. sibbaldii*, Gray)	4
Sejhval (*B. borealis*, Lesson)	1
Humpback (*Megaptera longimana*, Rud.)	1
Sperm Whales (*Physeter macrocephalus*, L.)	6

Of the fifteen taken before June 26, eleven were Finners and four Sperm Whales.

III.—*Measurements and Proportions.*

(See Tables at the end of this Report.)

In continuing the series of measurements adopted by Burfield, who followed True,[3] we found that in some cases it was not easy to determine the points from which measurements were taken, within six inches or a foot. We therefore fixed on a series of standards which enabled us to make measurements from corresponding points on every whale. These points I attempt to define as follows:—

(1) *Total length.* Taken between a position opposite the end of the upper jaw to a point opposite the notch between the flukes, in a straight line. When, as in the case of our first two whales, and in the cases of those taken before our arrival, we obtained the Norwegian measurements, two points had to be observed: (*a*) that Norwegian feet are equal to 12½ English inches; (*b*) that the Norwegians measured to the tip of the lower jaw, which projects beyond the rostrum, and therefore an allowance must be made for this in reducing to 'total length' according to our standard. Eighteen inches was the allowance made, and this was probably erring on the side of taking off too little rather than too much.

(2) *Tip of snout to anterior end of the groove between the spiracles.* This line is quite sharply marked.

(3) *Tip of snout to posterior insertion of pectoral fin.* This measurement and the next were taken on the dorsal side of the animal.

(4) *Tip of snout to posterior insertion of dorsal fin.* This fin slopes away behind as well as in front. The 'posterior insertion' was therefore found in the following manner—a line being dropped from the apex of the dorsal fin, at right angles to the body, the point where it cut the outline of the body was taken as the posterior insertion of the dorsal fin. Apart from this method I do not think that any point of equal value in every specimen could have been found.

(5) *Tip of snout to centre of eye.*

(6) *Centre of eye to anterior end of auditory slit.*

(7) *Notch of flukes to posterior end of anus.*

(8) *Notch of flukes to anterior margin of umbilicus*, which was the most definite border of that area.

[3] *Smithsonian Contributions to Knowledge*, vol. xxx.

Measurements of the Pectoral Fin.

(9) *Length of anterior border.* There is an eminence at the anterior, proximal end of the pectoral fin. Immediately anterior to this is a slight depression. The eminence marks approximately the position of the head of the humerus. Our measurement was taken from the tip of the flipper, along the anterior margin, to the centre of the eminence.

(10) *The posterior length* was taken from the tip, along the margin, to the axilla. This measurement was not easy to take, as the flipper was almost always directed backwards and the axilla compressed. When this was the case the exact point of proximal measurement had to be found by judgment, as the size of the limb and the rigidity of the muscles attached to it entirely prevented any attempt at altering the attitude of the fin.

(11) *The median length* was taken from the tip in a straight line, down the centre of the flipper, to a point on a line drawn through the axilla in such a manner as to carry on the outline of the body. In taking this measurement the idea was to estimate the extent to which the limb projects from the body.

(12) *The greatest breadth of the pectoral fin* was generally found to be about half-way between the tip and the insertion.

(13) *The length of the dorsal fin* was taken from the posterior insertion as defined above, and the anterior insertion, which could usually be found with moderate accuracy. This measurement cannot be regarded as more than approximate.

The flukes had been cut off every whale before it was towed in, but on *B. musculus* (No. 19) the right fluke had not been completely severed. Measurement gave 7 ft. 5 in. as the distance between tip of fluke and caudal notch. The spread of the flukes was therefore 14 ft. 10 in.

Total Length.

The following table shows the averages of total length of the five species taken, and a more detailed analysis of the total measurements of the Finners at different stages. I have taken as the minima for adult males and females the dimensions adopted by Burfield,[4] who followed True:—

Finners (*B. musculus*, L.)

		Ft.	in.
Average length of all finners	(37)	59	9
,, ,, ,, females	(17)	60	7
,, ,, ,, males	(20)	59	0
,, ,, ,, adult females	(12)	64	0
Maximum for females		69	8
Minimum for females		48	7
Average for adult males	(16)	60	8
Maximum for males		66	0
Minimum for males		46	7

[4] *Op. cit.*, p. 160.

It may be useful to compare these results with those of Burfield, who gives similar statistics for the year 1911:—

	1911.		1913.		
	Ft.	in.		Ft.	in.
Average for all specimens (53)	63	0	(37)	59	9
" " females (21)	64	3	(17)	60	7
" " males (25)	62	5	(20)	59	0
" " mature females (20)	64	8	(12)	64	0
" " " males (23)	63	2	(16)	60	8
Maximum females	75	0		69	8
" males	68	9		66	0
Minimum females	54	3		48	7
" males	53	3		46	7

As all the figures for 1913 are perceptibly smaller than the corresponding figures of Burfield for 1911, it suggests the probability that the larger whales are being killed off, although it would be useful to have the figures for other years in order to verify the diminution in size which appears to be taking place.

Blue Whales (*B. sibbaldii*, Gray).

All the Blue Whales taken in the 1913 season were brought in during our stay:—

	Ft.	in.
July 10, female	78	2
Aug. 18, "	70	7
" 20, "	68	6
Sept. 9,	68	0

Comparing these also with Burfield's figures [5] for the same species we have:—

	1911.		1913.		
	Ft.	in.		Ft.	in.
Average for all females (4)	75	4	(4)	71	$3\frac{3}{4}$
Maximum for females	84	0		78	2
Minimum for females	64	6		68	0

True gives 72 ft. as the minimum for mature females, but our second specimen (70 ft. 7 in.) had a fœtus 8 ft. long, and was therefore an adult animal. (True's figure was based upon two specimens only.)

Sperm Whales (*Physeter macrocephalus*, L.).

Ten Sperm Whales were taken in 1913; of these six were taken after our arrival, and all the specimens were males.

	Ft.	in.
Average of all Sperm Whales (10), males	58	3
Maximum, Sperm Whales	62	6
Minimum " "	53	0

Sejhval (*Balænoptera borealis*, Lesson).

One specimen only taken in 1913, female . . . . . 46 ft. 7 in.

Humpback (*Megaptera longimana*, Rud.).

Only specimen taken, male . . . . 45 ft. 8 in.

[5] *Op. cit.*, Table IV., p. 161.

IV.—*General Observations on the Various Species.*

1. Finners (*B. musculus*, Gray).

(*a*) *Colouration.*—None of the specimens of the Finner examined by us presented any remarkable colour variations. On very many animals white marks occurred in the pigmented areas, as noted by Burfield.[6] Some of these seemed to be the scars left after *Penella* has dropped off. In many cases we found the sores which had been produced by the parasite, although the latter was not present. These sores presented the same appearance as the wounds in which the parasites were still fixed.

Notes on individual specimens:—

No. 10.—There were a few white patches on the tongue, which may have been the result of lesions, or due to mere absence of pigment.

No. 11.—A pale, grey line, about three-eighths of an inch broad, but gradually widening, ran from the ear aperture upwards and backwards to a point level with the anterior margin of the pectoral fin, and about 9 in. above the level of the ear-hole. From here onwards it broadened out and swept round in a semicircle to the anterior margin of the pectoral. On the top of the head there was a triangular grey patch, having as apices the angle of the jaw, the nape at the level of the pectoral, and a point about half-way down the margin of the rostrum.

No. 19.—The fœtus of No. 19, 15 ft. in length, displayed the same areas of colouration on the head as an adult. The dark colour of the body was defined in front by the same line sweeping back from the eye, through the ear, and down to the pectoral, while dorsally it was limited by another line curving backwards, and dorsally, from the eye.

No 24.—The black colour extended in flecks from the left as far as the mid-ventral line, in the region of the ventral furrows.

No. 29.—The belly had a yellow tinge, but, as the animal was very decomposed, this was probably not the case during life, as, when they have been dead for some time, whales become very discoloured. There were streaks of black on the left side of the belly.

There is always a certain amount of pigment in the more lateral and posterior furrows. In Nos. 41 and 42 this was specially well developed, extending almost to the mid-ventral line from the left side. The furrow region of No. 42 had also a number of pale purple stains in its pure white. These were due to the presence of blood in the cutaneous vessels, which appeared to be gorged. They resembled bruises, but the epidermis was undamaged. This whale displayed a few of the 'galvanised-iron' markings which are characteristic of the Blue Whale. These were in the post-anal region. It had also several incised wounds in the belly, about 8 in. long, partly healed, but still raw. No. 45 had a large island of black pigment on the posterior furrow region of the left side.

[6] *Op. cit.*, 175.

There are frequently extensive white patches on the dark area, caused by the chafing of the whale against the side of the steamer as it is being towed in. These, however, are easily distinguished from the naturally unpigmented areas.

(*b*) *Ventral Furrows.*—In the Finner the number of pectoral furrows is exceedingly variable. We found a maximum of eighty-four, and a minimum of fifty-four. In nearly half of the cases a median furrow could be distinguished, the presence of which appears to have escaped notice up to the present. The number was estimated by finding the median furrow, and counting all those between it and the pectoral fin of the side which happened to lie uppermost. As the fin is approached the furrows become less marked, and it is not easy to discern the furrow nearest the fin. The skin in the axillary region is much folded longitudinally, which further complicates matters. By doubling the number of furrows thus counted and adding the unpaired median an estimate of the total number was made. The furrows in the smallest fœtus (3 ft. 11 in.) were represented by mere lines, and could not be counted with accuracy. The folds of twenty-seven specimens were counted, of which twelve had no distinguishable median furrow. The average depth of these furrows was about ·68 in. (deduced from eight measurements), and the average horizontal distance between points above the middle lines of the same number of furrows was 1·85 in., varying from 1·37 in. to 1·96 in. These measurements were taken from a portion of blubber lying on the plane and not stretched in any way.

It is essential that the counting should always be made in the same position, as some of the folds do not run the whole length of the furrowed area. There does, however, appear to be a certain amount of uniformity in the folding, the shorter folds corresponding with each other in different whales, if not with absolute accuracy, at any rate nearly so.

(*c*) *Tongue.*—The colour of the tongue as a whole is dark grey, but the area which is the morphological upper surface, which is distinguishable from the morphological lower surface, shades off into pink towards the 'tip.'

2. Blue Whales (*B. sibbaldii*, Gray).

Colouration.—The only point to which I wish to draw attention is that there are some curious markings on the skin, especially ventrally, but not confined to that aspect. These markings take the form of curved, darker and lighter lines radiating from a common centre. The area of such markings is about 8 in. long and 4 in. wide. Where there is a number of markings crowded together, the appearance of the skin forcibly reminds one of the pattern produced on the surface of 'galvanised iron.' These markings occur in considerable abundance on large areas of the skin.

3. Sejhval (*B. borealis*, Lesson).

External Characters.—The solitary example of this species taken was a female. Although a small species (this specimen was only

46 ft. 7 in. long) it has a robust figure, and the dorsal fin is of great height as compared with that of the Finner. This specimen had been lying at the buoy from Thursday afternoon until it was hauled up on Saturday morning, and was therefore considerably decomposed. The dorsal surface was dark grey, as was also the post-anal area of the ventral surface. The pre-anal region was for the most part of white colour, asymmetrically arranged. There was a considerable amount of black blotching towards the left side of this area, and on this side the white area was continued backwards in a large patch. There was no white patch corresponding with this on the right side. The symphysis was pigmented, and here there was a whorled design similar to that on the skin of the Blue Whale as described above. The upper lips and the lower side of the anterior end of the rostrum were nearly black, and were finely tuberculated. The inner (palmar) surface of the pectoral fins was pale, streaky, greenish grey, with black streaks intermingling with the less dark flecks. The right side was a dark grey, nearly black. This may have been due to the fact that the right side had been more exposed to the sun than the left side as the animal lay at the buoy.

The ear aperture was small. The tongue presented an area which could be more readily recognised as the dorsal surface than in the case of the Finners.

4. Humpback (*Megaptera longimana*, Rud.).

External Characters.—The form of the single specimen taken was robust, reminding one somewhat of the figure of the Sperm Whale. The dorsal fin was placed far back and was much falcated, and of moderate height. The colour was slate-chocolate, but very dark, almost black. Pure white, splashed, ring-like marks occurred on the lower jaw and on the dorsal side of the pectoral fin. The outer sides of the right mandible and of the right upper jaw were white, but on the left only the inner sides were unpigmented. The ventral surface of the flukes was white. The ventral folds were few in number (23), and wide; running up the centre of each groove was a low ridge about ·375 in. high, of triangular section. The folds were about 4 in. wide and 5 in. apart. The median fold, with the next on each side, also the fold next the right pectoral fin, were mere narrow grooves.

There was a deep groove running from the angle of the jaw downwards and backwards to a point about one-third of the width of the pectoral fin from its anterior margin. Another groove ran from a point a little above and in advance of the termination of this groove to a point somewhat behind the posterior margin of the pectoral, and a little above it. Unlike the small external auditory aperture of the Balænopterids the opening in this specimen was 8 in. long. The upper surface of the snout had the characteristic knobs of the species. In the mid-dorsal line there were five, the first being 11 in. from the tip of the snout, and the last 13½ in. from the spiracle. The spaces between the knobs, running from the snout, were 10½, 18, 12½, 23¼ in. respectively. There were also two series of

lateral knobs, following the margins of the rostrum, nine on each side in a consecutive row. Inside these rows, at their posterior ends, was a second series of four knobs on each side. The knobs of the inner, short row were set beside those of the outer row, forming pairs with them. But the two sides were not symmetrical. Thus, if the knobs of the outer row are numbered 1 to 9 from before backwards, on the left side 7, 8, and 9 were paired, and there was a single knob of the inner row behind the termination of the outer series. On the right side 6, 7, 8, and 9 were paired, and there was no unpaired knob posteriorly. Several of the left-side knobs had a hair on the summit, which suggests that the knobs may be overgrown hair-papillæ, and their arrangement does correspond fairly closely with the arrangement of the hairs of *Balænoptera*. On the symphysis there were four knobs on the right side and five on the left. In each case there was a vertical row of three. The knobs varied in size, a large one being 2 in. high and 4 in. across the base.

The eye appears to be rather more movable than in *Balænoptera*. The pectoral fin has an exceedingly irregular posterior margin. There were seven conspicuous elevations on it, varying in length from 10 to 27 in.

5. Sperm Whale (*P. macrocephalus*, L.).

(*a*) *External Characters.*—Six specimens were examined. The general body-colour is pale greyish chocolate, rather more lead-like ventrally. Between the genital aperture and the umbilicus there is a splashed chevron-shaped mark of a pale grey colour. The apex is on the umbilicus, and directed forwards, the 'arms' being about 4 ft. apart at the tips. There are also irregular grey flecks all over the ventral surface. In some specimens the front of the head is barred horizontally with streaks which are almost white in colour. They are broadest in the middle and taper towards the ends. The whole of the head, and in particular the anterior, ventral, and lateral areas, have numerous weals and sucker marks which have been produced by the arms and suckers of the cuttlefish, which are the main food of this species. As might be expected from the fact that the suckers of many of the molluscs are armed with chitinous teeth, the sucker marks take the form of rings of minute pricks. One such mark was 3½ in. across. The fifth Sperm Whale had a large patch of pure white on the umbilicus, and an extensive array of grey streaks on the left side, in addition to the grey chevron.

(*b*) *Spiracle.*—In every case the left spiracle alone was functional. On the right side, however, after the blubber has been removed, there is a compressed cavity, approximately oval in shape, about 18 in. long and 10 in. wide, in the position corresponding with that of the obliterated right spiracle. The lining of this cavity is heavily pigmented with the same colour as the outer surface of the animal. There can be no doubt that this is the vestige of the right spiracle, although no passage was observed running backwards from it in the direction of the pharynx.

(*c*) *Mouth.*—The palate and floor of the mouth have a general pale grey colour and have a large number of small grooves, about

an inch in length, running longitudinally. On the palate of the first Sperm Whale there were two large dark blotches. That on the left was about 8 in. long, that on the right 11 in.

(*d*) *Tongue.*—The tongue of *Physeter* affords a striking contrast to that of a Mystacocete. It is an exceedingly hard, strong structure of comparatively small size, and very nearly occludes the throat as the animal lies on the plane with the jaw gaping open. The tongue stands up from the jaw to a height of about 2 ft., and, as viewed from the front, presents a smooth, round wall, like the side of a section of wide tubing. The upper surface is wrinkled, and in front is produced into a small projection, which appears to correspond with the tip of the normal mammalian tongue. From its structure the tongue would appear to be of use in preventing the ingress of water during respiration, but in the dead animal, at any rate, this very fact of its nearly closing the throat gives the impression that the organ would be a hindrance to the swallowing of large prey. That this cannot be the case, however, is apparent from the size of the cuttlefish which we found in the stomach of one specimen, as described in Section V.

(*e*) *Teeth.*—Teeth occur in both jaws. Only those of the lower jaw can, however, be of much practical value in the capture of food, as the upper-jaw teeth are of small size, and often nearly covered with soft tissue. The lower-jaw teeth are about twenty in number on each side, and are arranged in pairs, but the two teeth of each pair are not exactly opposite to one another.

Actual numbers of teeth in the different Sperm Whales examined:—

Number 15	left side	21	right side	23
,, 16	,,	19	,,	19
,, 21	,,	20 plus 2	,,	21 plus 1
,, 22	,,	—	,,	—
,, 25	,,	24	,,	23
,, 26	,,	20	,,	21

The two most anterior teeth of each side project somewhat forward, but the majority of the teeth are nearly vertical, being somewhat recurved in most cases and having a slight inclination outward. The acuteness of the point is very variable, but this may be merely due to differences in age of the animals. One tooth was seen which had been broken off, but the stump did not appear to be at all decayed. In the palate there is a hollow corresponding with each tooth of the lower jaw, into which the latter fits when the mouth is shut.

The upper-jaw teeth are small, inclining backwards, and deeply embedded in soft tissue, but they do have some little use, as is demonstrated by the fact that in many cases they are much worn down by contact with the lower-jaw teeth. The most posterior of the latter are also very small, and of little use, occurring very far back. There were no teeth in the upper jaw of Nos. 16 and 26.

	Teeth in upper jaw—			
Number 15	left side	5	right side	7
,, 16	,,	0	,,	0
,, 21	,,	8	,,	7
,, 22	,,	—	,,	—
,, 25	,,	7	,,	7
,, 26	,,	0	,,	0

(*f*) *Dorsal Fin.*—The dorsal fin of the Sperm Whale consists of a prominent elevation, which rises to a height of from 14 to 18 in. above the line of the back. The fin is succeeded by a series of about six much smaller prominences which decrease in size towards the tail. None of these at all approaches the altitude of the dorsal fin. They are, nevertheless, quite obvious. On the ventral surface the keel of the caudal region is continued forwards towards the anus as a much more definite ridge than in the Balænopterids.

(*g*) *Flipper.*—The shape of the flipper is somewhat variable. In No. 21 the left pectoral appeared to have been damaged at some period, as there was a large notch on the preaxial side of the tip.

(*h*) *Spermaceti.*—In every specimen the quantity of this substance was large, usually constituting about one-third of the total oil yield of a whale of this species. It occurs all over the body as well as in the head, but no attention is paid to it except in the head, the rest merely contributing to the general production of 'sperm oil.' In the head there are three extensive cavities, an anterior single cavity and two lateral cavities. They all occur in the interior of a huge mass of exceedingly dense, fibrous connective tissue, which, when drained of spermaceti, is of a snowy whiteness. This mass constitutes the great bulk of the head, and rests upon the large cup-like structure formed by the bones of the rostrum. The cavities do not appear to possess definite linings, and when the oil runs out, masses of light, spongy tissue filled with the liquid fat run out also, as if they had been loosely attached to the walls of the cavity. They are probably liberated by the instruments introduced through the wall of the cavity in the process of tapping the spermaceti.

The following is the method of tapping. After the whale is flensed, the body is cut off from the head, which is left lying on its side. The whole head is covered by a thick coat of mixed muscle and tendon running longitudinally. The tendons are conspicuous, and may be removed in considerable lengths with little difficulty. The cutting of the hole in this capsule is an arduous work, and may occupy nearly an hour. A mid-dorsal and an anterior aperture are made, and when the cavities have been penetrated, the spermaceti runs out as if from a pipe. A movable wooden gutter is placed beneath the hole, by means of which the oil is run into the two open boilers, in which it is cooked.

Spermaceti is an almost colourless, transparent liquid, having a pale yellow tinge. It has not any noticeable odour, and the flavour is very faintly fishy, resembling that of a fresh duck egg. After boiling, the oil has a dark yellow colour while liquid. When cold, both before and after boiling, it sets stiff, but is not hard, the consistency being about that of lard. The uses of this oil have been indicated in the Introduction.

From the position of the spermaceti, and also of the blow-hole in *Physeter*, the following function of the former may be suggested: The food of the Sperm Whale is, in the main, composed of cuttlefish such as *Architeuthis*. As these forms are bathypelagic, it follows that the whales must descend to considerable depths to feed, and

remain submerged while feeding.[7] A very rapid ascent would be exceedingly advantageous after a prolonged immersion, and the more rapid the ascent which could be made the longer the immersion could be continued. In order to be able to ascend as speedily as possible, it would be of the greatest advantage to possess a large mass of some material, having a lower specific gravity than that of water, which would act as a float, and such a material spermaceti is. Moreover, as the mass of the spermaceti is placed in the head, and as it is of enormous size, even compared with the great mass of a Sperm Whale, the animal will always ascend head first, and probably nearly vertically, with the result that the first portion of the body to come above the surface will be the upper edge of the snout, the precise situation of the spiracle. It would appear, if this suggestion be correct, that in order to descend and to maintain a submerged condition, muscular exertion is necessary, whereas ascent is automatic, and is merely accelerated by swimming movements. These two points are in keeping with the habits of the whale as indicated above. It is possible that the astounding feat which has been credited to *Physeter*, that of hurling itself bodily out of the water, is really the result of a hurried ascent from a considerable depth, which has been so rapid that the animal has shot out of the water on reaching the surface.

V.—*Food of Different Species of Whale.*

The stomachs of all the species of Mystacocetes examined contained the remains of *Meganyctiphanes norvegica* (M. Sars), sometimes in immense quantities. Nothing else was ever seen, except some fragments of flesh on one occasion, but there can be little doubt that these had been driven into the stomach by the explosion of the harpoon. No fish of any sort were seen in the stomachs of any of these whales.[8]

The stomachs of the Sperm Whales invariably contained large quantities of cuttlefish beaks, which might be readily divided into large and small sizes, but, apart from size, there was nothing to differentiate the two series of beaks (fig. 1). A practically complete specimen of one of the molluscs was found in the stomach of No. 22 (the fourth Sperm Whale). The following measurements were taken on this animal:—

	Ft.	in.
Length of the mantle	6	0
Circumference of mantle	4	0
Length of the eight short arms	6	0
,, ,, tentacles	21	0
Length of tail	1	7
Width of caudal fin	1	9½
Diameter of largest sucker	0	1

In addition to this specimen, we saw fragments of others of approximately the same size. The following specimens were preserved: tip of tentacle, beak and radula in liquid, and a quantity of beaks and part of an internal shell in the dry state. An examination

[7] *Vide* Burfield, *op. cit.*, p. 155 [8] *Vide* Burfield, *op. cit.*, p. 178.

of these remains leaves little doubt that the species is *Architeuthis harveyi*, Verrill [9]—the caudal fin was too much digested to indicate whether it had been sagittate or not. The distal series of small, smooth suckers are not now on the tentacle tip, but these again may have been

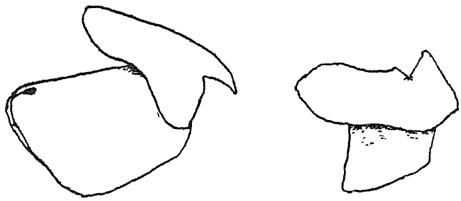


FIG. 1.—*Architeuthis harveyi*. Beak. Circ. $\frac{1}{1}$.

lost owing to the same cause. No soft parts of any of the smaller cuttlefish were found.

The molluscs appear to be quite lively when swallowed, as there are scars on the heads of the whales right up to the angle of the mouth. These have been produced by the vain efforts of the molluscs to save themselves. Sucker-marks were seen on the inside of one of the whales' stomachs. Two or three jawbones of some species of predaceous fish were found in the stomach of one Sperm Whale, but, except for these, nothing but cuttlefish remains were ever noticed.

VI.—*Notes on a Few Miscellaneous Specimens Preserved.*

(*a*) One of the Norwegians gave us an object, taken from whale No. 5 (Finner), which was stated to have been 'inside the ribs.' This appears to be a pathological structure. It is a flattened, oblong object about $2\frac{1}{4}$ in. long, and 2 in. wide, and about $\frac{3}{4}$ in. thick. At one point there seems to have been a peduncle. The entire specimen has a very hard capsule of fibrous connective tissue, and is filled with a more or less rèticulate mass, containing what may have been a coagulable fluid. There is a certain amount of calcification in the outer layers just beneath the capsule, and a little fat is visible on treatment with Sudan III. The conclusion to which the structures observed point is that this is a region of connective tissue, which has become infiltrated with some pathological product, and has acquired the thick capsule in consequence of its abnormal condition. The infiltrating material is very varied, in some parts it takes magenta brilliantly, while in others it stains in a very faint manner. The more brilliantly coloured tissue appears more homogeneous than that which refuses to take the stain. The colour of the capsule is dark brownish-grey, that of the contents a deep cream (fig. 2, No. 1).

(*b*) There are numerous roundish glandular objects embedded in the fat which lies in the mid-dorsal region of the body cavity of the Finner and surrounds the great vessels. These are lymphatic glands. One such specimen preserved is of very irregular shape. It is $1\frac{1}{2}$ in. in greatest length and $1\frac{1}{2}$ in. in greatest breadth (fig. 2, No. 2).

[9] *Trans. Conn. Acad. of Arts and Sciences*, Vol. 5, Pt. 1, p. 197 (1880).

(c) A number of greenish bodies were taken from a similar position in the Sperm Whale. The specimens are about 2½ in. long, about 2 in. wide, and ¾ in. thick, at the thickest part. The histological condition is exceedingly bad, as was to be expected from the general state of all the Sperm Whales which we saw. There is a connective-tissue capsule, and a great mass of the body is composed of the same tissue. There are two or three objects which may be sections of medullated nerves, and a number of rather thick-walled blood-vessels. No other structures can be recognised.

(d) The rectum of *Physeter* has an exceedingly well-developed cuticular lining for the last four or six feet of its length. In the

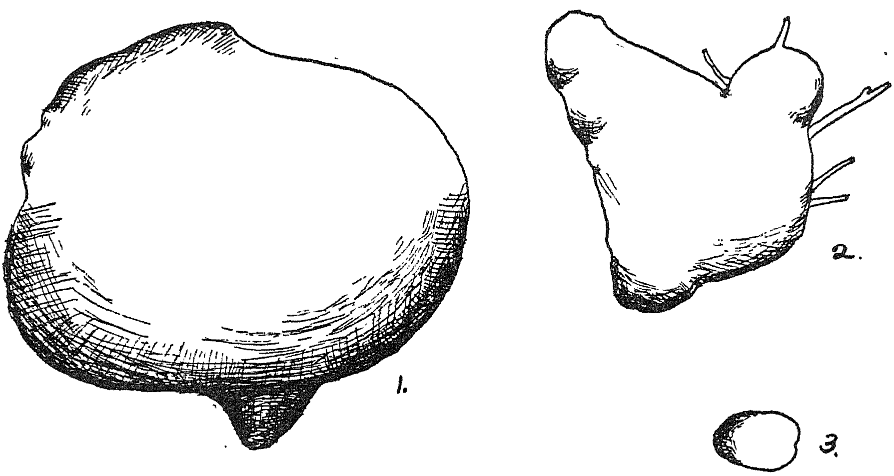


FIG. 2.—1. Calcified Body, from Finner No. 5. 2. Lymphatic Gland, Finner. 3. Cysticercus, from *Physeter*. (All natural size.)

first specimen in which it was observed the lining was detached owing to decomposition, but in a later example it was found to be attached to the remainder of the intestinal wall. This lining is about ⅛ in. thick. It has a pale yellow colour, and is of a consistency somewhat resembling that of a very hard-boiled egg. It is laminated, and can be readily split into layers. At irregular distances on the surface are hollows, penetrating partly or completely through the lining. The edges of these hollows have a puckered appearance. The line of junction of this lining with the mucosa of the intestine is perfectly sharp. The lining thins out very much just prior to its cessation, and the edges of successive laminæ are readily observed. The actual thickness of the lining where it comes to an end is $\frac{1}{16}$ in. The colour of the mucous membrane, which is fairly tough, is a dull pink, very much stained with sepia. Longitudinal sections of this region at the point of junction clearly show that this is a cuticle derived from the stratified epithelium of the rectum. The cuticle comes to a very abrupt termination, where it joins the mucosa, the line of

junction being very obvious in the slides. The epithelial layer is about half as thick as the cuticular.

VII.—*Parasites.*

1. External.

(*a*) *Balænophilus unisetus* (Aurivillius). We have nothing to add to Burfield's remarks on this species.[10]

(*b*) *Penella* (Kov. and Dan.). This parasite was observed on few of the whales examined, and only on the Finner. Three specimens were preserved, which vary in length from $5\frac{3}{4}$ in. to 10 in. No males were found as a result of the examination of these females. We frequently found white scars upon the skin of *B. musculus*, which were apparently healed wounds caused by *Penella*. The scars took the form of small oval marks about $\frac{3}{10}$ in. long and $\frac{1}{5}$ in. wide. Beneath the white area the epidermis is more firmly adherent than in other parts of a preserved specimen, which supports the view that these are healed wounds. We often found open wounds on the whales, which had evidently been produced by this parasite.

All the *Penella* which we saw occurred at the beginning of the season, and in the latter part of it only wounds from which the Copepods had fallen were observed. It may therefore be suggested that the period of attachment of the parasite to the whale is less than a year.

(*c*) *Coronula diadema* (L.), &c. On the Humpback there were large quantities of this species on the tips and especially on the posterior margins of the flippers. They were also found on the ventral furrows, and some small specimens were adhering behind the penis.

A number of specimens of *Conchoderma aurita* (L.) occurred among the *Coronula*, as well as a good number of small specimens of *Cyamus*, which last parasite was also generally scattered over the head region. On *Physeter* No. 15 four specimens of *Cyamus* were also found on the throat region, where there are a few short wrinkles. On the tip of the lower jaw of Sperm Whale No. 16 there was a small colony of *Conchoderma aurita*, while another specimen of the same species was taken from the second tooth of the left side of the lower jaw of Sperm Whale No. 25.

2. Internal.

(*a*) *Trematodes.*—*Monostomum plicatum* (Creplin) was found in the intestines of the following Finners: 1, 3, 19, 23, 24, 27, 30.

(*b*) *Nematodes.*—We found nematodes, which appear to be of the genus *Ascaris*, in the stomachs of every Sperm Whale examined. They are generally very abundant. In the renal vein of the *Megaptera* the mass of nematodes described later was found, and in the posterior vena cava of *B. sibbaldii*, No. 33, a solitary, incomplete specimen of another nematode was taken. These worms all appear to belong to the Strongylidæ. As mentioned later, in the digitate structure observed in the veins of *B. musculus* nematode eggs were found, as was also

[10] *Op. cit.*, p. 179.

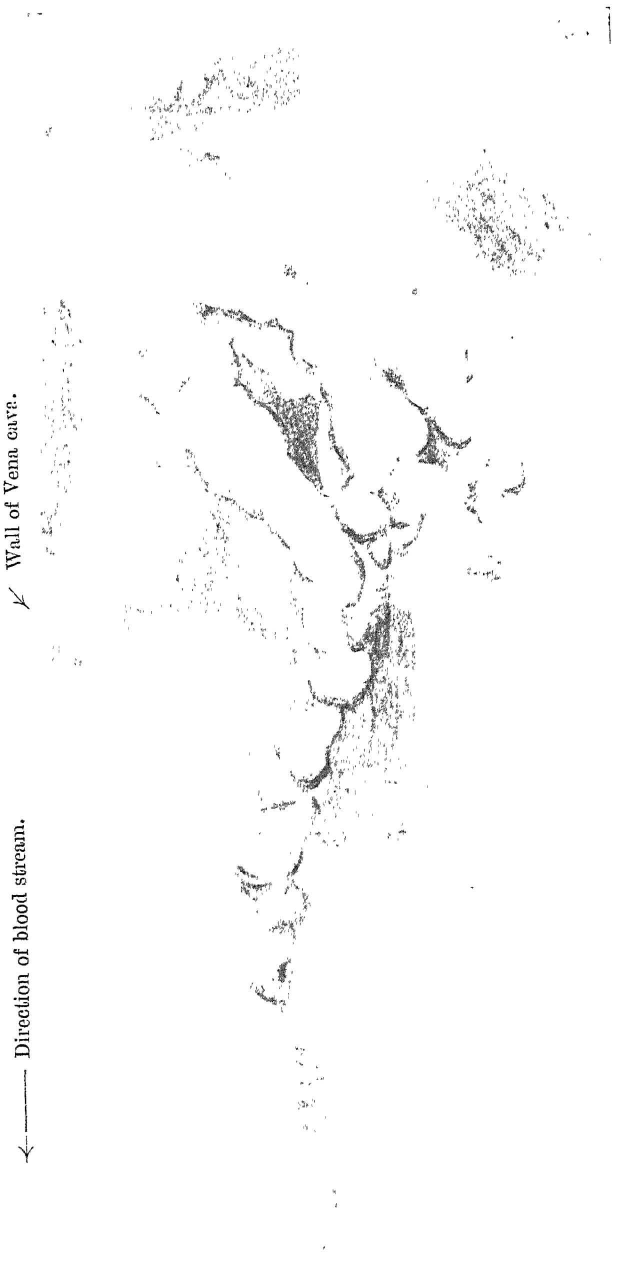


Fig. 3.—Digitate form of Pathological Structure caused by Nematode Worms. $\times \frac{3}{1}$.

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the case in the neighbourhood of the mass of the worms found in the Humpback.

(*c*) *Acanthocephali.*[11] Representatives of this group were found in every species except *B. borealis*.

B. musculus,	*Echinorhynchus*	*porrigens* (Rudolphi), new host.
B. sibbaldii	,,	*porrigens* in small intestine, new host.
,,	,,	*brevicollis* (Malm).
M. longimana	,,	*porrigens*, large intestine.
P. macrocephalus	,,	*capitatus* (von Linstow), new host.
,,	,,	*brevicollis* (Malm).

(*d*) *Cestodes.*—One of the Norwegians drew our attention to a large number of soft white bodies embedded in the blubber of one of the Sperm Whales. They occurred in a more or less irregular manner at a depth of from 1½ to 6 in. from the outer surface. Each body is enclosed in a cyst with fibrous walls from which it is readily detached. The accompanying figure (fig. 2, No. 3) is taken from a specimen in good condition and undistorted. Sections of these bodies clearly demonstrate that they are the cysticercus stage of some Cestode. The proscolex occurs at one of the poles of the long axis. The Prince of Monaco's account of the capture of a Sperm Whale off the Azores in 1895 mentions numerous cysticerci in the blubber of that animal, which are probably identical with those here described.[12]

(*e*) *Structure found in the renal veins and posterior vena cava* (see figs. 3 and 4).

In whale No. 8 ♂, while searching for the suprarenal, we came across a series of short, digitate processes, hanging into the lumen of the vena cava at the point of entrance of the renal vein. A similar structure occurred in whales Nos. 12 ♂, 13 ♂, 27 ♂, 30 ♀, 32 ♂, all Finners. In two of the Blue Whales, Nos. 17 ♀ and 33 ♀, it was also present, as well as in *Megaptera*, No. 28 ♂, but in the last in a somewhat different form. In some specimens, owing to the manner in which the kidney was cut away from the body in removing the entrails, it was impossible to say whether the structure had been present or not. No trace of it was found in any of the Sperm Whales examined.

The specimens preserved are four in number, all differing from one another. The accompanying figures show the two larger specimens. Fig. 3 is an example of the most digitate form. This specimen is not actually in the renal vein, but projects from the wall of the vena cava close to the point of entrance of the renal vein. The digitate processes are not actually tubular, but contain cavities, which in the free ends are nearly continuous, so that the whole process is here practically a blind sac. The diameter of the processes increases from the free end towards the wall of the vena cava. The digitations unite at the point of attachment, and the structure thus formed is continued beyond the wall of the vein towards the kidney. It is most unfortunate that we were unable to preserve a specimen

[11] *Vide* A. E. Shipley, *Archives de Parasitologie*, II., No. 2, p. 262, 1899.
[12] *Bull. Mus. Nat. Hist., Paris*, t. 1, p. 308, 1895.

sufficiently large to show whether there is an actual connection with the kidney itself. But from notes taken at the Station, I find that in one of the Blue Whales this structure was followed up, and that branches of the renal vein were found blocked by it in the proximal region of the kidney. This was also the case in the Humpback, No. 28.

The interior of the digitations shows the cavities above mentioned, separated from each other by walls of connective tissue continuous with the tissue of the walls of the tube. In section the wall is seen to be composed of fibrous connective tissue very dense externally, but more open in the inner layers, where there are also some nodules of lymphoid tissue. The partitions between adjacent cavities come off from the inner layers of the outer wall. There are a few blood-vessels in these structures. The cavities are filled with material which varies in consistency from that of a rather stiff pulp to a stony hardness. In the latter case the material contains a varying amount of inorganic salts, chiefly calcium phosphate, of which there may be as much as 80 per cent. present. These concretions are very hard in the fully calcified condition, and are rounded in form in the Finners, but more rod-like in specimens taken from a Blue Whale and the Humpback. The soft material varies in its composition. In its softest state it is easily teased out in water, and is then seen to be composed of a mass of nematode eggs. Although the shells are very thick, and resist the action of pure nitric acid and of strong alkali, they are very transparent, and embryos may be seen in their interiors in stages of development varying from morula-like masses to small coiled worms. In the partially calcified material it is still possible to separate by teasing numbers of these ova, which are here covered with the calcium deposit. On the application of mineral acid the inorganic material dissolves away, leaving the ova distinctly recognisable as such.

Fig. 4 shows a specimen which is confined to the renal vein, and has no digitations hanging into the vena cava. There is a single cylindrical body about 6 in. long attached to the wall of the renal vein by strap-like bands of varying breadth tapering somewhat towards their junctions with the body. Sections of this body show the thick wall, partitions, and congregations of ova, as described above. The ova appear to be embedded in a matrix nearly homogeneous, but containing numerous small rounded bodies, which stain darkly with Ehrlich's hæmatoxylin. They may be nuclei, and in that case indicate that the matrix is probably cellular. In the renal vein of *Megaptera* a mass of tissue was found of an elongated form, and containing hard calcareous material together with a number of tangled nematode worms, which appear to belong to the family Strongylidæ. The worms were mostly enveloped in sheathing tissue attached to the wall of the vein, but the sheath was not always complete.

There can be little doubt that the presence of these worms affords the key to the formation of the growths described above. It is known that the presence in a vein of any object the surface of which is not smooth, or of lesions of the intima of a blood-vessel, produces

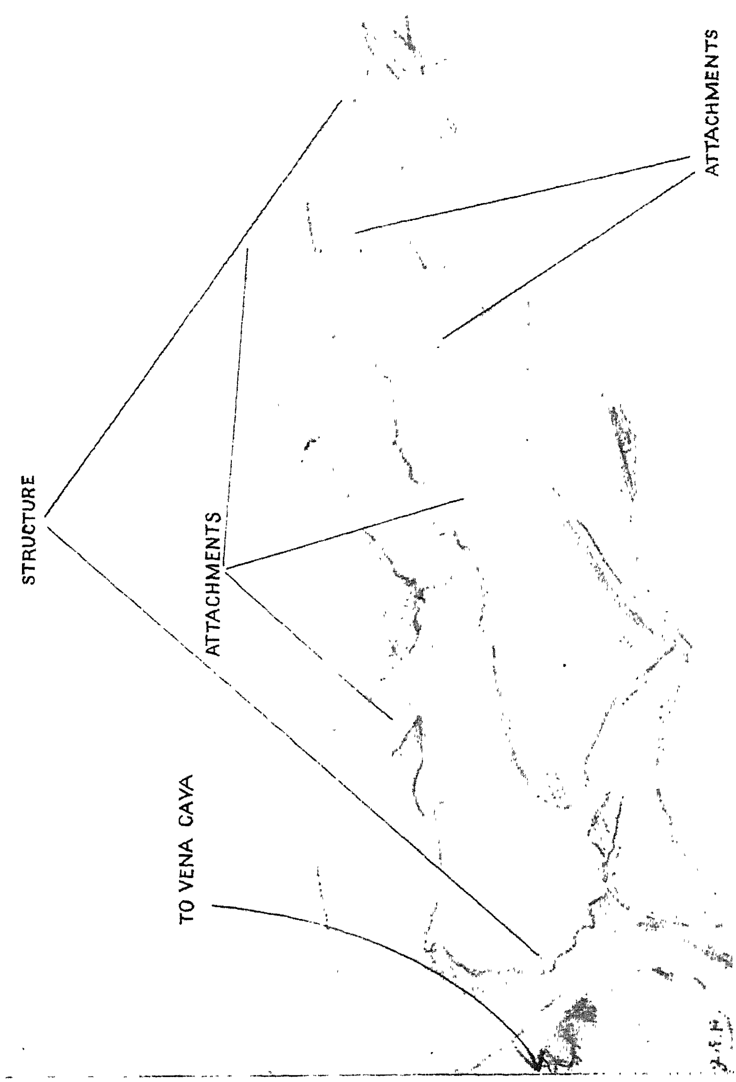

FIG. 4.—Renal Vein opened, showing Enclosed Structure caused by Nematodes. Slightly foreshortened. Circ. 1/1.

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a thrombus, which may in the course of time become organised.[13] The organisation takes the form of a proliferation of the fibrous tissue of the blood-vessel wall, which in the course of time entirely replaces the thrombus. This tissue may be supplied with blood-vessels. Thrombi may become calcified, and the deposition of calcium salts is one of the striking features of the structures under consideration. Again, metazoan parasites have been known to cause thrombi,[14] and in the cases before us it is highly probable that the nematodes have produced vascular lesion, or the mere presence of the eggs may have been sufficient to excite coagulation of the blood. From either of these causes the thrombi may have been formed, becoming subsequently organised. It is interesting to note in this connection that pedunculated, if not digitated, thrombi have occurred in the human subject. The thrombus in *Megaptera* appears to have actually *enclosed* the worms which caused it, and they have been retained by the subsequent organisation.

VIII.—*Fœtuses.*

B. musculus.—None of the fœtuses examined by us were sufficiently small to be of use for embryological purposes. They were all perfectly formed, and even in the smallest (3 ft. 11 in.) the ventral furrows of the adult were represented by mere lines.

Table VI. contains a list of the fœtuses, and a detailed list of measurements will be found in Table XII. It may be noted that the 8 ft. fœtus of No. 30 was mutilated by some of the workers before we arrived on the scene, while that of No. 31 was destroyed before the female was opened, apparently by the harpoon explosion. The sizes of both of these are therefore estimates only. The fœtus of No. 47 (9 ft. 4 in.) was in a hopeless state of decomposition, and very few measurements could be taken upon it.

(*a*) *Body form.*—In all the fœtuses which we saw the form was the same as in the adult, but in the smallest it was noticeably more robust.

(*b*) *Colouration.*—This character does not differ from that of the adult animals. The dark tint is found in the same situations. The smaller fœtuses are very much less pigmented. In the 3 ft. 11 in. fœtus the whole skin was gorged with blood, and the black colour was confined to the following localities: back, tip of dorsal fin, tip of flippers, tips of flukes, tip of rostrum, and symphysis.

B. sibbaldii.—One specimen, 7 ft. 7 in. in length, was seen. The upper surface was pale grey, the distal part of the dorsal fin and the external mouth parts were stained with black.

IX.—*Breeding Season of the Balænopterids.*

A factor which may be used in attempting to ascertain the probable breeding season of the large whales is the sizes of the fœtuses observed at different times. Leaving for this purpose the Blue Whale out of

[13] Macfarlane, *Text Book of Pathology*, 1904 ed., pp. 107-8. Green, *Manual of Pathology*, 11th ed., p. 66.
[14] Green, *op. cit.*, p. 389.

account, because very few of this species have been seen in the pregnant condition, the six fœtuses which we saw have the following dimensions:

	Ft.	in.
July 15	15	0
Aug. 7	8	0
„ 7	4	0
„ 27	7	10
Sept. 4	3	11
„ 9	9	4

Burfield's table of fœtuses observed in 1911 is as follows:—

	Ft.	in.
July 12	8	11
„ 16	4	11
„ 20	8	5
„ 24	6	0
Aug. 7	5	6
„ 11	9	0
Sept. 10	9	0
„ 18	9	3

The young whale appears to be about 20 ft. long when born. If the size of the fœtus is proportional to the length of gestation which has elapsed since pairing until the time when the fœtus is measured, and if the period of gestation is ten months,[15] then the fœtuses found must have been the result of pairings at approximately the times given opposite each in the table which follows:—

	Ft.	in.		
July 15	15	0	age 7½ months, pairing took place	December–January.
Aug. 7	8	0	„ 4 „ „ „	April (beginning).
„ 7	4	0	„ 2 „ „ „	June.
„ 27	7	10	„ 4 „ „ „	April (end).
Sept. 4	3	11	„ 2 „ „ „	July (beginning).
„ 9	9	4	„ 5 „ „ „	May.

Pursuing the same idea with the 1911 fœtuses, we have:—

	Ft.	in.		
July 12	8	11	age 4½ months, pairing took place	March (beginning).
„ 16	4	11	„ 2½ „ „ „	May (beginning).
„ 20	8	5	„ 4½ „ „ „	March (beginning).
„ 24	6	0	„ 3 „ „ „	April (end).
Aug. 7	5	6	„ 3 „ „ „	May.
„ 11	9	0	„ 5 „ „ „	March–April.
Sept. 10	9	0	„ 5 „ „ „	May (beginning).
„ 18	9	3	„ 5 „ „ „	May.

These times can only be regarded as approximate, even if the premises upon which they are based be correct. It is, however, suggested by this table that pairing may take place at any time between the end of December (the first in the 1913 series) and the beginning of July (fifth in the 1913 table), at intervals of roughly two months. This would indicate that the Balænopterids are, at any rate, polyœstrous, and in season in December (February?), April, and June. All females would not be fit for breeding actually simultaneously, but the precise time would vary for different individuals, and

[15] Burfield, *op. cit.*, p. 155.

this would account for some pairings occurring at such times as the beginning of July or the beginning of May.

Such cases would belong to the June and April œstra respectively. It is probable that such an arrangement would be advantageous. As the whale is a pelagic animal and individuals are widely separated, a frequently recurring breeding condition would be of great advantage to an animal in which pairing is to a greater or less extent casual. The above suggestion, which was originated by Mr. Daniel, appears to afford a possible explanation of the extraordinary variability in the sizes of the fœtuses, apparently without regard to the season, a circumstance which the idea of a definite monœstrous condition does not elucidate. (It is interesting to note that on June 13, 1913, at the Inishkea Station a fœtus only 5 in. long was found, which must have been but a week or two old, *i.e.*, of the June pairing, according to the preceding method of reckoning the pairing times. It was, most unfortunately, not possible to preserve it.)

X.—*Additional Notes.*

(*a*) *Extinction.*—The whalemen state that of the whales which they see they are able to take only about one in ten. The animals are therefore perhaps not in immediate danger of being actually killed out. The most serious risk lies in the fact that the largest, and therefore the adult, whales are being exterminated. True gives as the minimum length of adult animals 55 ft. 7 in., as no pregnant females of less dimensions have been recorded. Now the whalers will take *anything* over 40 ft., with the result that the animals which have attained sexual maturity are in the gravest danger of being killed out. That the largest whales *are* being exterminated, the fall in general size at Blacksod between 1911 and 1913 may indicate. This means that the whales which are capable of reproduction are being destroyed. By the time that it is no longer profitable to hunt whales,[16] it appears likely that the adults will have been so thinned out that they will no longer be able to reproduce with sufficient profusion to compensate for natural casualties. When this occurs the whales will be well within sight of extinction.

(*b*) *Capture of Blue Whales.*—Of all the species which it is profitable to pursue the whalers state that the Blue Whale is the wildest, and they will not hunt this species if other game is to be had. A Blue Whale on perceiving the pulsations of the propeller of the approaching steamer is usually startled, and, if alarmed, at once rushes off at full speed. Since this represents something like twenty miles per hour, it is quite useless for the boat to pursue the fleeing animal, the speed of the steamer being only ten or twelve miles per hour. When the whalers are bent on catching a Blue Whale, it is sometimes necessary to accompany the animal for three or four days, until it becomes accustomed to the presence of the steamer, which can then approach within range, and the whale is speedily disillusioned as to the harmlessness of the now familiar object.

(*c*) *Migration Movements.*—During the earlier part of the season the Mystacocetes are stated to travel in a north-easterly direction,

[16] Burfield, *op. cit.*, p. 153.

during the later part in a south-westerly. If this be so, it may be concluded that the latter is the return journey of those whales which have passed north in the beginning of the season.

The solitary Humpback, taken on July 25, was moving in a direction the reverse of that which the Finners and Blue Whales were pursuing at the same time.

The only Sejhval which was captured was brought in on September 6, a fact which is to be noted in connection with the whalers' statement to Burfield,[17] that the Sejhval disappears by the end of June.

The following is the explanation which the whalers give of the occurrence of Sperm Whales in these Northern waters. In the Southern seas each adult male is the leader of a herd of females, and as the young bulls approach maturity they are driven off by the old leader. These young bulls do not become leaders of herds, as they are inferior in strength and size to the fully adult males. But when fully grown they seek out herds, and contend with the leaders for the possession of the females. If the old males are then driven off, they become solitary wanderers, and frequently travel up into the North Atlantic. In connection with this theory it may be mentioned that the Sperm Whales taken at Blacksod and Inishkea are all males, and of great size for Sperm Whales, which seldom exceed 60 ft., the average for the ten Blacksod specimens being 57 ft. 3½ in., while the smallest was 53 ft.

TABLE I.—*B. musculus.* Table of Specimens Taken.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.	Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
—	May 16	—	59	6	14	July 5	♀	54	7
—	,, 28	—	62	6	18	,, 11	♀	59	4
—	,, 31	—	59	6	19	,, 15	♀	67	3
—	June 14	—	61	6	20	,, 15	♂	59	3
—	,, 19	—	61	0	23	,, 20	♀	48	7
—	,, 20	—	53	0	24	,, 20	♀	53	7
—	,, 21	—	68	6	27	,, 25	♂	66	0
—	,, 22	—	61	6	29	Aug. 5	♀	57	5
—	,, 22	—	64	6	30	,, 7	♀	69	8
—	,, 22	—	64	6	31	,, 7	♀	65	0
—	,, 23	—	64	6	32	,, 16	♂	57	7
1	,, 26	♀	69	4	35	,, 27	♀	63	3
2	,, 26	♀	50	7	36	,, 28	♂	58	5
3	,, 28	♂	64	1	37	,, 29	♀	62	3
4	,, 28	♂	63	1	38	,, 29	♀	55	2
5	,, 30	♂	64	0	39	,, 30	♂	58	3
6	,, 30	♀	66	9	40	,, 30	♀	60	8
7	July 2	♂	61	0	41	Sept. 1	♂	56	2
8	,, 2	♂	62	0	42	,, 2	♂	61	6
9	,, 3	♂	60	0	43	,, 4	♀	59	10
10	,, 3	♂	55	2	44	,, 5	♂	52	10
11	,, 3	♂	58	1	45	,, 5	♂	58	0
12	,, 4	♂	55	0	47	,, 8	♀	62	8
13	,, 4	♂	46	7	48	,, 8	♂	63	5

[17] *Op. cit.*, p. 154.

TABLE II.—*B. sibbaldii*. List of Specimens.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.	Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
17	July 10	♀	78	2	34	Aug. 20	♀	68	6
33	Aug. 18	♀	70	7	49	Sept. 9	♀	68	0

TABLE III.—*B. borealis*. One Specimen.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
46	Sept. 6	♀	46	7

TABLE IV.—*M. longimana*. One Specimen.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
28	July 25	♂	45	8

TABLE V.—*Physeter macrocephalus*. List of Specimens Taken.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.	Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
—	May 26	♂	57	9	16	July 9	♂	56	3
—	,, 26	♂	61	4	21	,, 16	♂	60	6
—	,, 31	♂	62	6	22	,, 18	♂	57	3
—	June 14	♂	60	5	25	,, 23	♂	53	0
15	July 8	♂	57	5	26	,, 25	♂	56	2

TABLE VI.—Fœtuses. *B. musculus*.

No. of Parent	Date when Measured	Sex	Total Length Ft.	in.
19	July 15	♂	15	0
30	Aug. 7	♀ ?	8	0 (circ.)
31	,, 7	—	4	0 (circ.)
35	,, 27	♀	7	10
43	Sept. 4	♂	3	11
47	,, 8	♂	9	4

TABLE VII.—*B. sibbaldii*. One fœtus.

No. of Parent	Date when Measured	Sex	Total Length Ft.	in.
33	Aug. 18	♂	8	0

TABLE VIII.—*B. musculus*. Measurements.

Number of Whale	No. 1 ♀		No. 2 ♀		No. 3 ♂		No. 4 ♂		No. 5 ♂		No. 6 ♀		No. 7 ♂		No. 8 ♂		No. 9 ♂		No. 10 ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	69	4	50	7	64	1	63	1	64	0	66	9	61	0	62	0	60	0	58	1
Tip of snout to spiracle	—		—		—		—		9	4	11	0	8	8	10	4	9	4	9	0
Tip of snout to posterior insertion of pectoral fin	—		—		25	5	20	0	20	11	21	6	17	9	20	7	18	10	18	2
Tip of snout to posterior insertion of dorsal fin	—		47?	7?	43	4	43	9	43	0	—		45	0	48	8	46	4	44	9
Tip of snout to centre of eye	—		—		13	3	13	0	—		13	7	11	0	12	7	11	1	11	1
Symphysis of jaw to centre of eye	—		—		—		—		—		16	6	12	10	16	5	14	6	13	1
Centre of eye to anterior end of ear aperture	—		—		2	4	3	4	2	11	3	6	2	9	3	6	2	9	2	8
Notch of flukes to posterior end of anus	—		13	1	12	4	11	0	16	4	18	6	16	5	17	9	17	1	15	8
Notch of flukes to anterior margin of umbilicus	—		(to posterior umbilicus) 26	4	28	4	24	1	28	6	30	6	26	0	29	9	28	10	26	2
Length of pectoral fin, tip to anterior insertion	—		—		7	10	—		7	4	7	7	6	10	8	3	7	4	7	2
Length of pectoral fin, tip to posterior insertion	—						—		5	3	5	4	5	2	5	7	5	2	4	7
Median length of pectoral fin	—		—		6	3	—		—		6	2	6	0	7	3	6	0	5	9
Pectoral fin, greatest breadth	—		—		1	4	1	8½	1	5	1	10	1	5	—		1	8	—	
Dorsal fin, length	4	10	4	6	4	3	4	5	4	8	4	2	3	1	4	2	4	1	2	8
Dorsal fin, vertical height	1	4	1	5	1	7	1	6	1	3	1	7	1	5	1	8	1	6	1	5
Number of ventral furrows	—		—		—		—		54		68		76		70		—		67	

TABLE VIII.—*B. musculus.* Measurements (*continued*).

Number of Whale	No. 11 ♂		No. 12 ♂		No. 13 ♂		No. 14 ♀		No. 18 ♀		No. 19 ♀		No. 20 ♂		No. 23 ♀		No. 24 ♀		No. 27 ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	55	2	55	0	46	7	54	7	59	4	67	3	59	0	48	7	53	7	66	0
Tip of snout to spiracle	9	2	8	9	7	0	8	0	10	3	10	9	9	1	6	7	8	2	9	6
Tip of snout to posterior insertion of pectoral fin	18	10	18	0	14	7	17	11	20	0	23	0	20	0	15	6	17	9	19	7
Tip of snout to posterior insertion of dorsal fin	42	1	42	7	35	7	42	4	46	2	52	8	46	6	36	11	40	10	54	0
Tip of snout to centre of eye	11	1	10	11	8	9	14	0	12	8	13	4	11	6	9	2	11	1	11	10
Symphysis of jaw to centre of eye	12	4	13	1	10	3	12	2	15	9	16	6	13	7	—		12	11	14	1
Centre of eye to anterior end of ear aperture	2	9	2	6	2	7	2	8	3	0	3	1	3	4	2	6	2	9	3	2
Notch of flukes to posterior end of anus	15	8	15	9	12	8	17	4	17	10	19	3	—		14	4	15	3	15	6
Notch of flukes to anterior margin of umbilicus	25	3	27	1	21	11	27	0	28	10	33	1	—		22	7	25	6	25	11
Length of pectoral fin, tip to anterior insertion	6	9	7	3	5	3	—		7	8	7	8	7	0	6	8	7	9	6	4
Length of pectoral fin, tip to posterior insertion	4	9	4	11	4	0	—		5	2	5	2	5	0	4	0	4	7	4	8
Median length of pectoral fin	5	9	6	2	4	7	—		6	0	6	0	6	6	5	10	5	10	5	7
Pectoral fin, greatest width	1	5	1	6	1	3	1	6	1	10	1	0	1	7	1	4	1	6	1	7
Dorsal fin, length	6	9	4	11	2	7	2	3	3	5	3	10	3	0	2	8	2	6	3	2
Dorsal fin, vertical height	1	3	1	4	1	0	1	1	1	5	1	6	1	1	1	2	0	11	1	6
Number of ventral furrows	62		71		65		—		59		68		73		56		77		69	

TABLE VIII.—*B. musculus.* Measurements (*continued*).

Number of Whale	No. 29 ♀		No. 30 ♀		No. 31 ♀		No. 32 ♂		No. 35 ♀		No. 36 ♂		No. 37 ♀		No. 38 ♀		No. 39 ♂		No. 40 ♀	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	57	5	69	8	65	0	57	7	63	3	58	5	62	3	55	2	58	3	60	8
Tip of snout to spiracle	9	11	12	2	11	2	9	6	10	0	9	1	11	1	9	7	9	8	9	8
Tip of snout to posterior insertion of pectoral fin	18	4	21	9	21	3	18	9	18	11	18	3	20	6	18	2	19	2	19	10
Tip of snout to posterior insertion of dorsal fin	45	1	54	6	56	3	44	3	46	3	45	9	48	0	42	3	44	10	45	7
Tip of snout to centre of eye	11	11	13	0	13	1	11	1	12	1	—		12	5	—		12	1	11	8
Symphysis of jaw to centre of eye	—		15	10	15	3	—		13	11	—		15	0	—		14	5	13	10
Centre of eye to anterior end of ear aperture	2	8	3	1	2	11	2	4	3	4	2	7	3	4	2	7	2	11	2	10
Notch of flukes to posterior margin of anus	15	6	19	5	18	0	16	4	16	4	1	0	17	5	15	3	16	11	17	0
Notch of flukes to anterior margin of umbilicus	26	3	30	10	29	5	27	8	27	0	—		28	9	25	8	28	1	29	2
Length of pectoral fin, tip to anterior insertion	6	6	7	8	6	4	—		7	5	7	8	8	0	8	0	6	10	6	10
Length of pectoral fin, tip to posterior insertion	5	3	5	8	5	10	—		5	5	4	9½	5	9	5	0	4	9	4	9
Median length of pectoral fin	5	6	6	8	5	1	—		6	4	5	7	6	10	6	0	5	7	5	5
Pectoral fin, greatest breadth	1	9	1	9	1	9	—		1	10	1	7	1	9	1	5	1	7	1	7
Dorsal fin, length	—		3	7	3	3	3	6	4	11	3	6	2	5	3	8	4	4	3	0
Dorsal fin, vertical height	—		2	1	1	2	1	4	1	9	1	2	1	2	1	1	1	5	1	6
Number of ventral furrows	67		61		84		—		59		—		—		62		63		64	

TABLE VIII.—*B. musculus.* Measurements (*continued*).

Number of Whale	No. 41 ♂		No. 42 ♂		No. 43 ♀		No. 44 ♂		No. 45 ♂		No. 47 ♀		No. 48 ♂	
	Ft.	in.	Ft.	in	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	56	2	61	6	59	10	52	10	58	0	62	8	63	5
Tip of snout to spiracle	9	5	9	10	9	10	8	9	9	10	9	11	11	0
Tip of snout to posterior insertion of pectoral fin	18	3	19	9	18	6	17	9	19	2	20	8	21	7
Tip of snout to posterior insertion of dorsal fin	42	11	47	10	47	6	41	7	46	1	47	9	49	3
Tip of snout to centre of eye	12	0	11	8	11	10	10	5	11	10	12	1	12	11
Symphysis of jaw to centre of eye	14	2	14	3	14	2	12	8	14	3	14	6	—	
Centre of eye to anterior end of ear aperture	2	8	3	2	2	10	2	9	2	10	2	10	3	0
Notch of flukes to posterior margin of anus	15	9	14	11	16	9	14	7	15	8	17	9	17	9
Notch of flukes to anterior margin of umbilicus	26	7	27	4	28	5	24	6	27	0	29	10	29	0
Length of pectoral fin, tip to anterior insertion	6	6	7	5	7	9	6	6	7	3	8	1	—	
Length of pectoral fin, tip to posterior insertion	4	8	5	3	4	11	4	4	4	8	5	8	—	
Median length of pectoral fin	5	4	6	6	6	6	5	11	6	5	6	8	—	
Pectoral fin, greatest breadth	1	5	1	9	1	8	1	6	1	7	1	9	—	
Dorsal fin, length	3	0	3	7	3	2	3	7	4	0	3	9	3	6
Dorsal fin, vertical height	1	3	1	3	1	3	1	6	1	7	1	10	1	2
Number of ventral furrows	75		61		65		—		64		64		65	

Measurements.—TABLE IX. *B. sibbaldii.* TABLE X. *B. borealis.* TABLE XI. *Megaptera longimana.*

Number of Whale	No. 17 I. ♀		No. 33 II. ♀		No. 34 III. ♀		No. 49 IV. ♀		No. 46 I. ♀		No. 38 I. ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	78	2	70	7	68	6	68	0	46	7	45	8
Tip of snout to spiracle	12	6	12	3	12	5	11	0	7	8	7	11
Tip of snout to posterior insertion of pectoral fin	27	9	24	0	24	2	21	10	15	9	16	5
Tip of snout to posterior insertion of dorsal fin	67	6	55	6	53	3	52	0	32	10	30	10
Tip of snout to centre of eye	16	2	15	2	14	10	13	6	9	6	11	11
Symphysis of jaw to centre of eye	20	2	18	0	17	10	16	5	11	7	13	6
Centre of eye to anterior end of ear aperture	—		3	3	3	7	3	4	2	5½	2	7¼
Notch of flukes to posterior margin of anus	22	3	19	6	19	7	19	5	12	2	10	11
Notch of flukes to anterior margin of umbilicus	35	7	32	6	30	11	31	8	21	11	18	7
Length of pectoral fin, tip to anterior insertion	11	0	11	10	11	6	11	0	6	8	14	4
Length of pectoral fin, tip to posterior insertion	7	7	7	10	8	0	7	8	4	8	12	0
Median length of pectoral fin	8	9	9	0	9	9	8	10	5	9	12	9
Pectoral fin, greatest breadth	3	0	2	7	2	9	2	6	1	3½	3	4
Dorsal fin, length	3	1	2	4	2	11	2	8	2	10	4	8
Dorsal fin, vertical height	0	10	0	7½	0	8	0	11	2	1	1	5
Number of ventral furrows	69		73		60		64		47		23	

TABLE XII.—*Physeter macrocephalus.*—Measurements.

Number of Whale	No. 15 I. ♂		No. 16 II. ♂		No. 21 III. ♂		No. 22 IV. ♂		No. 25 V. ♂		No. 26 VI. ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	57	5	56	3	60	6	57	3	53	0	56	2
Front of snout to posterior pectoral	24	0	24	2	25	3	22	9	21	9	24	6
Front of snout to posterior dorsal	40	0	39	3	41	9	38	3	37	8	—	
Tip of upper jaw to angle of mouth	—		10	0	10	11	10	11	11	5	11	1
Tip of lower jaw to angle of mouth	10	3	9	9	10	5	10	8	11	9(?)	11	0
Notch of flukes to posterior margin of anus	—		15	9	17	9	16	2	12	6	15	4
Notch of flukes to anterior margin of umbilicus	(anus to umbilicus) 12	0	26	2	27	6	26	11	22	9	—	
Length of pectoral fin, tip to anterior insertion	5	3	5	1	4	10	4	7	4	0	4	9
Length of pectoral fin, tip to posterior insertion	4	0	3	3	3	6	2	3	1	8	1	9
Median length of pectoral fin	4	9	4	1	3	8	3	6	3	6	4	0
Pectoral fin, greatest breadth	2	9	2	6	3	1	2	7	2	5	2	6
Dorsal fin, length	4	4	5	0	4	5	6	3	4	6	6	0
Dorsal fin, vertical height	1	2	1	2	1	10	1	3	1	6	1	4
Length of head, dorsal	—		—		21	10	—		18	10	20	0
Half circumference, just behind mouth	15	2	15	9	—		—		—		—	
Height of head, at anterior end of mouth	10	0	—		10	11	—		8	1	9	3
Width of snout	5	3	—		5	3	—		4	7	5	3

Measurements.—Fœtuses.—TABLE XIII. *B. musculus.* TABLE XIV. *B. sibbaldii.*

Number of Parent	No. 19		No. 30		No. 35		No. 43		No. 47		No. 33	
Sex of Fœtus	♂		♀		♀		♂		♂		♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	15	0	—		7	10	3	11	9	4	7	7
Tip of snout to spiracle	1	11	—		1	$0\frac{3}{4}$	0	6	—		1	$0\frac{1}{2}$
Tip of snout to posterior insertion of pectoral fin	4	6	3	$6\frac{3}{4}$	2	$4\frac{1}{2}$	1	3	—		2	7
Tip of snout to posterior insertion of dorsal fin	11	2	—		6	0	2	11	—		5	$10\frac{1}{2}$
Tip of snout to centre of eye	2	8	2	2	1	$5\frac{1}{4}$	0	$8\frac{3}{5}$	—		1	5
Symphysis of jaw to centre of eye	3	1	—		1	$7\frac{3}{4}$	0	$9\frac{3}{4}$	—		1	7
Centre of eye to anterior end of ear aperture	—		0	8	0	$5\frac{1}{2}$	0	$3\frac{1}{4}$	—		0	$6\frac{1}{4}$
Notch of flukes to posterior margin of anus	4	$3\frac{1}{2}$	—		2	2	1	$1\frac{3}{8}$	—		2	5
Notch of flukes to anterior margin of umbilicus	6	9	—		3	$7\frac{1}{4}$	1	$9\frac{3}{8}$	—		3	8
Length of pectoral fin, tip to anterior insertion	2	4	1	10	1	1	0	6	1	2	1	4
Length of pectoral fin, tip to posterior insertion	1	8	1	$2\frac{3}{4}$	0	$8\frac{1}{2}$	0	$4\frac{1}{2}$	0	11	0	$10\frac{3}{4}$
Median length of pectoral fin	1	$10\frac{1}{2}$	1	$6\frac{3}{4}$	0	10	0	5	1	1	1	$0\frac{3}{4}$
Pectoral fin, greatest breadth	0	$6\frac{1}{4}$	0	$4\frac{3}{4}$	0	$2\frac{3}{4}$	0	$1\frac{3}{8}$	0	$3\frac{1}{2}$	0	$3\frac{3}{4}$
Dorsal fin, length	1	6	—		0	6	0	$1\frac{5}{8}$	0	7	0	$4\frac{1}{2}$
Dorsal fin, vertical height	0	5	—		0	$3\frac{1}{4}$	0	1	0	$3\frac{1}{2}$	0	1
Width of flukes, tip to tip	3	$6\frac{1}{2}$	3	$2\frac{1}{2}$	1	$9\frac{3}{4}$	0	9	—		1	11
Number of ventral furrows	73		71		49		52		—		83	

TABLE XV.—*B. musculus*. Proportions.*

Number of Whale	No. 1 ♀	No. 2 ♀	No. 3 ♂	No. 4 ♂	No. 5 ♂	No. 6 ♀	No. 7 ♂	No. 8 ♂	No. 9 ♂	No. 10 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	69 4	50 7	64 1	63 1	64 0	66 9	61 0	62 0	60 0	58 1
	%	%	%	%	%	%	%	%	%	%
Tip of snout to spiracle	—	—	—	—	14·53	16·48	14·21	16·29	15·55	15·50
Tip of snout to posterior insertion of pectoral fin	—	—	39·42	26·36	32·68	32·21	29·1	33·20	31·39	31·28
Tip of snout to posterior insertion of dorsal fin	—	—	67·62	69·36	67·17	—	73·77	78·48	77·23	77·07
Tip of snout to centre of eye	—	—	20·67	20·61	—	20·35	18·03	20·56	18·48	19·08
Symphysis of jaw to centre of eye	—	—	—	—	—	24·78	21·04	26·48	24·16	24·53
Centre of eye to anterior end of ear aperture	—	—	3·64	5·28	4·56	5·24	4·78	5·64	4·58	4·59
Notch of flukes to posterior end of anus	—	26·19	19·25	17·44	25·52	24·73	26·92	28·64	28·47	26·98
Notch of flukes to anterior margin of umbilicus	—	43·82	44·21	38·74	44·52	45·69	42·62	48·26	48·06	45·05
Length of pectoral fin, tip to anterior insertion	—	—	12·23	—	11·46	11·36	11·20	13·30	12·23	12·34
Length of pectoral fin, tip to posterior insertion	—	—	—	—	8·20	7·81	8·47	9·00	8·61	7·89
Median length of pectoral fin	—	—	9·75	—	—	9·24	9·61	11·69	10·00	9·90
Pectoral fin, greatest breadth	—	—	2·08	2·70	2·21	2·74	2·32	—	2·77	—
Dorsal fin, length	7·28	—	6·63	7·00	7·29	6·24	4·94	6·72	6·80	4·59
Dorsal fin, vertical height	2·1	—	2·47	2·37	1·95	2·37	2·32	2·68	2·50	2·43
Number of ventral furrows	—	—	—	—	54	68	76	70	—	67

* Proportions = measurements reduced to percentages of total length.

TABLE XV.—*B. musculus.* Proportions (*continued*).

Number of Whale	No. 11 ♂	No. 12 ♂	No. 13 ♂	No. 14 ♀	No. 18 ♀	No. 19 ♀	No. 20 ♂	No. 23 ♀	No. 24 ♀	No. 27 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	55 2	55 0	46 7	54 7	59 4	67 3	59 0	48 7	53 7	66 0
	%	%	%	%	%	%	%	%	%	%
Tip of snout to spiracle	16·65	15·92	13·23	14·66	17·06	15·99	15·39	13·80	15·24	14·40
Tip of snout to posterior insertion of pectoral fin	34·14	32·73	31·3	32·83	33·7	34·20	33·9	30·18	33·13	29·68
Tip of snout to posterior insertion of dorsal fin	76·28	77·53	76·38	77·57	77·8	78·30	78·81	71·86	76·21	81·83
Tip of snout to centre of eye	20·09	19·86	18·78	—	21·34	19·83	19·49	18·87	20·68	17·93
Symphysis of jaw to centre of eye	22·36	23·70	22·01	25·65	29·91	24·53	23·02	—	19·14	21·34
Centre of eye to anterior end of ear aperture	4·87	4·53	5·54	4·89	5·05	4·58	5·65	5·14	5·13	4·79
Notch of flukes to posterior end of anus	26·59	28·64	27·19	31·77	33·43	28·49	—	31·61	28·46	23·98
Notch of flukes to anterior margin of umbilicus	45·76	49·25	47·06	49·46	42·98	48·07	—	43·05	37·80	39·27
Length of pectoral fin, tip to anterior insertion	10·65	13·18	11·01	—	12·92	9·04	11·87	13·72	14·46	9·89
Length of pectoral fin, tip to posterior insertion	8·61	8·94	8·53	—	8·58	6·10	8·28	8·23	8·53	7·07
Median length of pectoral fin	10·42	11·21	9·84	—	10·11	8·92	11·02	11·10	10·88	8·46
Pectoral fin, greatest breadth	2·56	2·72	1·93	2·74	3·89	2·72	2·68	2·74	2·78	1·54
Dorsal fin, length	4·87	8·94	—	4·23	7·24	5·71	5·08	5·48	4·66	4·79
Dorsal fin, vertical height	2·26	2·42	2·14	1·98	2·38	2·23	1·83	2·31	1·71	2·27
Number of ventral furrows	62	71	65	—	59	68	73	56	77	69

TABLE XV.—*B. musculus.* Proportions (*continued*).

Number of Whale	No. 29 ♀	No. 30 ♀	No. 31 ♀	No. 32 ♂	No. 35 ♀	No. 36 ♂	No. 37 ♀	No. 38 ♀	No. 39 ♂	No. 40 ♀
Total length	Ft. in. 57 5	Ft. in. 69 8	Ft. in. 65 0	Ft. in. 57 7	Ft. in. 63 3	Ft. in. 58 5	Ft. in. 62 3	Ft. in. 55 2	Ft. in. 58 3	Ft. in. 60 8
	%	%	%	%	%	%	%	%	%	%
Tip of snout to spiracle	17·58	17·51	17·4	13·10	15·81	15·50	17·8	17·37	16·6	15·93
Tip of snout to posterior insertion of pectoral fin	35·22	31·29	33·11	27·37	29·90	31·27	32·94	32·18	32·91	32·70
Tip of snout to posterior insertion of dorsal fin	79·91	78·41	87·86	76·85	73·13	78·39	77·11	76·58	76·98	75·15
Tip of snout to centre of eye	21·12	18·70	20·39	19·25	19·11	—	19·95	—	20·75	24·21
Symphysis of jaw to centre of eye	—	25·65	23·77	—	21·96	—	23·38	—	24·75	22·80
Centre of eye to anterior end of ear aperture	4·72	4·43	4·54	4·05	5·27	4·42	5·35	4·68	3·97	4·67
Notch of flukes to posterior margin of anus	—	27·94	28·05	27·78	25·82	—	27·96	27·02	29·05	28·02
Notch of flukes to anterior margin of umbilicus	48·29	44·36	45·84	47·93	42·69	—	46·18	46·52	48·21	49·34
Length of pectoral fin, tip to anterior insertion	11·26	11·04	9·87	—	11·73	13·14	12·85	15·53	11·73	11·27
Length of pectoral fin, tip to posterior insertion	9·30	8·15	9·09	—	8·56	8·21	9·23	9·06	8·15	7·83
Median length of pectoral fin	9·74	12·08	7·92	—	10·01	9·56	10·97	10·87	9·58	8·93
Pectoral fin, greatest breadth	1·62	2·518	2·72	—	2·89	2·71	2·81	2·71	2·61	2·96
Dorsal fin, length	—	5·15	4·04	6·078	7·77	5·99	3·88	6·64	3·31	4·93
Dorsal fin, vertical height	—	2·92	1·81	2·31	2·76	1·99	1·87	1·96	1·86	2·47
Number of ventral furrows	67	61	84	—	59	—	—	62	63	64

TABLE XV.—*B. musculus.* Proportions (*continued*).

Number of Whale	No. 41 ♂	No. 42 ♂	No. 43 ♀	No. 44 ♂	No. 45 ♂	No. 47 ♀	No. 48 ♂
Total length	Ft. in. 56 2	Ft. in. 61 6	Ft. in. 59 10	Ft. in. 52 10	Ft. in. 58 0	Ft. in. 62 8	Ft. in. 63 5
	%	%	%	%	%	%	%
Tip of snout to spiracle	16·77	16·17	16·44	16·56	16·95	15·46	17·31
Tip of snout to posterior insertion of pectoral fin	32·48	32·46	30·93	33·59	33·04	32·98	34·03
Tip of snout to posterior insertion of dorsal fin	76·40	78·68	79·39	78·70	79·45	76·23	77·66
Tip of snout to centre of eye	20·77	19·59	19·78	19·72	20·40	19·29	20·36
Symphysis of jaw to centre of eye	24·62	26·16	23·69	23·97	24·57	23·14	—
Centre of eye to anterior end of ear aperture	5·04	5·20	4·73	5·20	4·88	4·52	4·73
Notch of flukes to posterior margin of anus	30·26	30·87	29·67	27·60	27·02	25·14	27·20
Notch of flukes to anterior margin of umbilicus	41·25	46·30	47·49	46·36	46·55	47·61	41·53
Length of pectoral fin, tip to anterior insertion	13·20	12·19	14·95	12·30	12·50	12·9	—
Length of pectoral fin, tip to posterior insertion	8·75	8·63	8·309	—	8·04	9·04	—
Median length of pectoral fin	11·57	10·69	10·86	11·20	11·06	12·27	—
Pectoral fin, greatest breadth	2·87	2·78	2·78	2·83	2·73	2·79	—
Dorsal fin, length	5·34	5·89	5·29	6·78	6·89	5·98	5·51
Dorsal fin, vertical height	2·22	2·05	2·08	2·83	2·73	2·92	1·84
Number of ventral furrows	75	61	65	—	64	64	65

Proportions.—TABLE XVI. *B. sibbaldii.* TABLE XVII. *B. borealis.* TABLE XVIII. *Megaptera longimana.*

	TABLE XVI. *B. sibbaldii.*				TABLE XVII. *B. borealis.*	TABLE XVIII. *Megaptera longimana.*
Number of Whale	No. 17 ♀	No. 33 ♀	No. 34 ♀	No. 49 ♀	No. 46 ♀	No. 28 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	78 2	70 7	68 6	68 0	46 7	45 8
	%	%	%	%	%	%
Tip of snout to spiracle	15·82	17·36	18·11	19·17	16·46	15·5
Tip of snout to posterior insertion of pectoral fin	35·13	34·00	35·28	32·10	33·82	33·94
Tip of snout to posterior insertion of dorsal fin	85·45	77·91	77·73	74·73	70·46	67·51
Tip of snout to centre of eye	20·46	21·49	21·65	19·86	20·38	26·09
Symphysis of jaw to centre of eye	25·53	25·51	26·05	24·14	24·83	29·56
Centre of eye to anterior end of ear aperture	—	4·60	4·15	4·90	5·18	5·65
Notch of flukes to posterior margin of anus	28·16	27·83	28·52	28·56	26·12	23·91
Notch of flukes to anterior margin of umbilicus	45·04	46·05	45·13	46·57	47·07	40·69
Length of pectoral fin, tip to anterior insertion	13·93	17·12	17·79	19·17	14·31	31·38
Length of pectoral fin, tip to posterior insertion	9·59	11·10	11·68	11·27	10·02	23·42
Median length of pectoral fin	11·08	12·75	14·23	12·99	12·34	27·92
Pectoral fin, greatest breadth	3·79	3·54	4·01	3·94	2·68	7·30
Dorsal fin, length	3·90	3·36	4·25	3·92	6·08	10·22
Dorsal fin, vertical height	1·05	·88	·97	1·34	4·47	3·10
Number of ventral furrows	69	73	60	64	47	23

TABLE XIX.—*Physeter macrocephalus* (L.). Proportions.

Number of Whale	No. 15 ♂	No. 16 ♂	No. 21 ♂	No. 22 ♂	No. 25 ♂	No. 26 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	57 5	56 3	60 6	57 3	53 0	56 2
	%	%	%	%	%	%
Front of snout to posterior pectoral	41·80	42·96	41·74	39·74	41·03	43·41
Front of snout to posterior dorsal	69·64	69·77	68·89	66·80	69·44	—
Tip of upper jaw to angle of mouth	—	17·78	18·04	18·92	21·54	19·73
Tip of lower jaw to angle of mouth	17·85	17·34	17·22	18·63	22·17(?)	19·58
Notch of flukes to posterior margin of anus	—	33·34	29·34	28·23	23·58	27·29
Notch of flukes to anterior margin of umbilicus	—	46·51	45·45	47·01	33·32	—
Length of pectoral fin, tip to anterior insertion	9·14	9·03	7·68	8·00	7·54	8·45
Length of pectoral fin, tip to posterior insertion	6·96	5·77	5·78	3·93	3·14	3·11
Median length of pectoral fin	8·27	7·25	6·06	6·11	6·60	7·12
Pectoral fin, greatest breadth	4·78	4·44	4·71	4·51	4·55	4·45
Dorsal fin, length	7·54	8·89	7·30	10·91	6·74	10·68
Dorsal fin, vertical height	2·03	2·07	3·02	2·18	1·51	2·37
Length of head, dorsal	—	—	36·10	—	35·53	35·60
Height of head, at anterior end of mouth	17·42	—	18·04	—	15·25	16·46
Width of snout	9·14	—	8·67	—	8·64	9·34

Fœtuses.—Proportions.—Table XX. *B. musculus.* Table XXI. *B. sibbaldii.*

No. of Parent	No. 19 ♂	No. 30 ♀	No. 35 ♀	No. 43 ♂	No. 47 ♂	No. 33 ♀
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	15 0	—	7 10	3 11	9 4	7 7
	%	%	%	%	%	%
Tip of snout to spiracle	12·77	—	10·77	12·77	—	13·74
Tip of snout to posterior insertion of pectoral fin	23·83	—	30·32	32·14	—	37·07
Tip of snout to posterior insertion of dorsal fin	74·44	—	76·6	74·47	—	77·49
Tip of snout to centre of eye	17·77	—	18·35	17·82	—	18·68
Symphysis of jaw to centre of eye	20·55	—	21·01	20·74	—	20·88
Centre of eye to anterior end of ear aperture	—	—	5·85	6·91	—	6·86
Notch of flukes to posterior margin of anus	28·61	—	27·04	28·34	—	31·87
Notch of flukes to anterior margin of umbilicus	45·00	—	46·02	46·01	—	60·88
Length of pectoral fin, tip to anterior insertion	15·84	—	13·82	12·76	12·61	17·58
Length of pectoral fin, tip to posterior insertion	11·11	—	9·04	9·35	9·82	11·81
Median length of pectoral fin	12·50	—	10·64	10·64	11·61	14·02
Pectoral fin, greatest breadth	3·47	—	2·91	2·81	3·12	4·12
Dorsal fin, length	6·66	—	6·38	3·53	6·25	4·67
Dorsal fin, vertical height	2·77	—	3·45	2·12	3·12	1·09
Width of flukes	23·61	—	23·14	19·14	—	23·08
Number of ventral furrows	73	71	49	52 (faint)	—	83

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Mr. E. S. GOODRICH (*Chairman*), Dr. J. H. ASHWORTH (*Secretary*), Sir E. RAY LANKESTER, Professor W. C. McINTOSH, Dr. S. F. HARMER, Professor S. J. HICKSON, Mr. G. P. BIDDER, Dr. W. B. HARDY, *and* Dr. A. D. WALLER.

THE British Association table at Naples has been occupied since the beginning of October 1913 by the Hon. Mary E. Palk, and from March 17 to April 15, 1914, by Mrs. H. L. M. Pixell-Goodrich. An application for the use of the table in September and October has been received from Mr. J. Mangan, M.A., Government School of Medicine, Cairo.

The following reports have been received:—

The Hon. Mary E. Palk reports: 'I have occupied the Naples table of the British Association since October last. I have been engaged on a revision of Professor Anton Dohrn's monograph of the Pycnogonida of the Bay of Naples. The work is slow because of the difficulty of preparing these animals, and the modifications I have made to Dr. Dohrn's work are chiefly histological. I have been unsuccessful in my attempts to study the habits of the living animal. I do not yet feel justified in publishing the results of my researches, as most of my conjectures require further proof, which it is not always easy to obtain.'

Mrs. H. L. M. Pixell-Goodrich reports: From March 17 to April 15, 1914, I occupied the British Association table at the Stazione Zoologica, Naples. During this time I searched for parasitic Protozoa in various marine invertebrates, and investigated chiefly stages in the development and sporogony of Lithocystis and Urospora of *Echinocardium cordatum* and Gonospora of *Glycera siphonostoma*. The results of these researches I hope shortly to publish.'

The Committee being wishful to encourage zoologists and physiologists to apply for the use of the table, and believing they are often deterred from applying by an exaggerated idea of the expense involved, prepared a statement giving an estimate of the cost of going to and living in Naples. A copy of this statement was sent to every zoological laboratory and most of the physiological laboratories in the United Kingdom. It is hoped that increased use will be made of the excellent facilities which the table offers for the prosecution of researches in Zoology and in the Physiology (including the chemistry) of marine organisms.

In the report for last year attention was drawn to the sum of 50*l*. remaining in the hands of the Committee. Professor Hickson, on retiring from the Chairmanship of the Committee, transferred this sum to the present Chairman. The Committee have therefore required only 50*l*. from the Association this year to complete the sum due for the upkeep of the table.

The Committee ask to be reappointed with a grant of 100*l*.

Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Professor SYDNEY H. VINES, Mr. E. S. GOODRICH, *and* Professor J. P. HILL, *appointed to nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.*

SINCE the date of the last report the use of the table has been granted to Mr. J. S. Dunkerly for one month for the purpose of investigating Protozoa, especially those parasitic in fish.

Experiments in Inheritance.—Final Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. R. DOUGLAS LAURIE (*Secretary*), Professor R. C. PUNNETT, *and* Dr. H. W. MARETT TIMS, *appointed to enable Mr. Laurie to conduct such Experiments.* (*Drawn up by the Secretary.*)

THE experiments were commenced in December 1907 with the object set forth in the first interim report presented to the Dublin Meeting of the Association in 1908. They were brought to an end in 1911, and some of the results summarised in the report to the Portsmouth Meeting that year. A more detailed account is now given in this final report.

The data concern in the main two matters: (A) the inheritance of yellow coat colour in mice, and (B) the inheritance of dense and dilute colourations in mice.

The following dense colours have come under my notice during the experiments: yellow, golden-agouti, cinnamon-agouti, black, and chocolate. On the presence and absence hypothesis,

homozygous	golden-agouti may be represented by zygotic formula	yy GG BB Ch Ch.
,,	cinnamon-agouti	,,	,,	,,	yy GG bb Ch Ch.
,,	black	,,	,,	,,	yy gg BB Ch Ch.
,,	chocolate	,,	,,	,,	yy gg bb Ch Ch.

where Y = factor for yellow colour (not barred).
G = ,, ,, barred arrangement of yellow colour found in hairs of agouti (grey) mice.
B = ,, ,, black colour.
Ch = ,, ,, chocolate colour.

Yellow appears to be always heterozygous, and zygotic formulæ representing various kinds of yellow mice may be arrived at by replacing yy of the above series by Yy.

Each of the above colours may occur in a dense form, in which the pigment is densely deposited, or in a dilute form; these dense and

Yellow × Yellow	Yellow	Golden-agouti	Cinnamon-agouti	Black, *i.e.*, dense black	Chocolate, *i.e.*, dense chocolate	Total
42 ♂ (ex yel. × yel.) × 44 ♀ (ex yel. × yel.)	4	1	—	—	—	5
494 ♂ (,, ,, ,,) × 1054 ♀ (,, ,, ,,)	1	—	2	—	—	3
15 ♂ (,, ,, ,,) × 18 ♀ (,, ,, ,,)	1 (45 ♂)	—	—	3	—	4
15 ♂ (,, ,, ,,) × 43 ♀ (,, ,, ,,)	2	—	—	1	—	3
15 ♂ (,, ,, ,,) × 44 ♀ (,, ,, ,,)	4 {67 ♂, 68 ♀, 69 ♂}	—	—	1	—	5
7 ♂ (,, ,, ,,) × 13 ♀ (,, ,, ,,)	4	—	—	1	—	5
891 ♂ (,, ,, ,,) × 893 ♀ (,, ,, ,,)	3 {1053 ♀, 1054 ♀}	—	—	1	—	4
890 ♂ (,, ,, ,,) × 823 ♀ (,, ,, ,,)	—	—	—	2	2	4
159 ♂ (,, ,, ,,) × 160 ♀ (,, ,, ,,)	2 (494 ♂)	—	—	—	1	3
820 ♂ (,, ,, ,,) × 821 ♀ (,, ,, ,,)	3	—	—	—	6	9
1303 ♂ (,, ,, ,,) × 1289 ♀ (,, ,, ,,)	6	—	—	—	2	8
1222 ♂ (,, ,, ,,) × 1221 ♀ (,, ,, ,,)	4	—	—	—	—	4
1222 ♂ (,, ,, ,,) × 1221 ♀ (,, ,, ,,)	3	—	—	—	2	5
(1) 67 ♂ (,, ,, ,,) × 68 ♀ (,, ,, ,,)	1	—	—	—	—	1
(1) 67 ♂ (,, ,, ,,) × 68 ♀ (,, ,, ,,)	5	—	—	—	—	5
(2) 494 ♂ (,, ,, ,,) × 160 ♀ (,, ,, ,,)	3	—	—	—	—	3
(3) 15 ♂ (,, ,, ,,) × 19* ♀ (,, ,, ,,)	2 (49 ♂)	—	—	—	—	2
506 ♂ (ex choc. ,,) × 823 ♀ (,, ,, ,,)	1	—	—	—	3	4
(4) 79 ♂ (ex blue ,,) × 1054 ♀ (,, ,, ,,)	3 (1303 ♂)	—	—	—	—	3

(4) (5)	79 ♂ (ex blue × yel.) × 1053 ♀ (ex yel. × yel.)	2 (1289 ♀)	—	—	—	—	2
	1349* ♂ (ex yel. × yel.) × 1183 ♀ (ex black × yel.)	3	—	—	—	—	3
	1040 ♂ (ex sil.-fawn ,,) × 1092 ♀ (ex blue × yel.)	2	—	—	1	—	3
	235 ♂ (ex choc. ,,) × 1184 ♀ (,, ,, ,,)	—	—	—	1	2	3
	1025 ♂ (ex sil.-fawn ,,) × 1101 ♀ (ex sil.-fawn × yel.)	—	—	—	2	1	3
	1025 ♂ (,, ,, ,,) × 1026 ♀ (,, ,, × ,,)	1	—	—	—	1	2
	83 ♂ (ex choc. ,,) × 87 ♀ (ex choc. × yel.)	2	—	—	—	1	3
	522 ♂ (,, ,, ,,) × 521 ♀ (,, ,, ,,)	2	—	—	—	2	4
	522 ♂ (,, ,, ,,) × 521 ♀ (,, ,, ,,)	2	—	—	—	—	2
	473 ♂ (ex sil.-fawn × yel.) × 474 ♀ (ex sil.-fawn × yel.)	2	—	—	—	1	3
	235 ♂ (ex choc. × yel.) × 1183 ♀ (ex black × yel.)	2 (1349 ♂)	—	—	—	—	2
	83 ♂ (,, ,, ,,) × 85 ♀ (ex choc. × yel.)	2	—	—	—	1	3
	Observed . . .	72	1	2	13	25	113
			$\underbrace{}_{41}$				
	Calculated 2 : 1 = 75·3		37·6				
	Calculated 3 : 1 = 84·75		28·25				

7 ♂, 13 ♀, 15 ♂, 18 ♀, 19 ♀ were obtained from reliable dealers and I was able to see their actual parents.

(1) 67 ♂ yel. × choc. gave yellow, black and chocolate.
68 ♀ yel. × sil.-fawn gave yellow and chocolate.

(2) 494 ♂ yel. × sil.-fawn gave yellow and cinnamon-agouti.
160 ♀ yel. × yel. gave yellow and chocolate.

(3) 15 ♀ yel. × choc. gave yellow and black.

(4) 79 ♂ yel. × sil.-fawn gave yellow, black and chocolate.
1054 ♀ yel. × sil.-fawn gave yellow and black.

(5) 1053 ♀ yel. × sil.-fawn gave yellow and black.

* See text discussion of matings, under (*a*).

dilute conditions are allelomorphic, and may be represented by presence or absence of the factor D.

Further, any of the above conditions may be present potentially, but remain undeveloped in absence of some colour-activating material which may be represented by factor C; in the absence of this factor the animal is an albino.

A. *The Inheritance of Yellow Coat Colour in Mice.*

In the first place, all my yellow mice appear to be heterozygous in respect of their yellow coat colour; none which have been fairly tested breeding true to yellowness, but on the other hand giving offspring which include, in addition to yellows, a proportion of individuals whose colour is other than yellow. Yellow is incompletely epistatic to black and chocolate. I find that, as Durham points out, black pigment may be present in the hairs of yellows throwing blacks, and chocolate pigment in the hairs of yellows throwing chocolates. Moreover, the degree of development of these other pigments in the hairs varies a good deal during the life of the animal.

The tendency to abnormal fattening of yellow mice pointed out by Durham was also evident in the mice used by me.

I arrange the matings which concern yellow mice in two tables: yellow × yellow, and yellow × other colour. The abbreviations in brackets indicate the immediate parentage of the mice concerned. Where the heterozygous nature of a yellow mouse is not shown in the table by its offspring a note is added of some additional mating showing it to be heterozygous (see tables on pp. 164, 165, and 168, 169).

I. In regard to the matings yellow × yellow given in the table on pp. 164 and 165 certain points may be noted:

(*a*) Twenty-six of the mice used were derived from the cross yellow × yellow, and expectation was that at least one-third of these would prove to be true-breeding yellows. There are only two, however (marked with asterisk), which could possibly answer to this condition, and there is no evidence about them beyond that given in the table. It will be seen that they produced only two and three young respectively. Matings with other mice designed to test them gametically proved sterile. It would evidently be inappropriate to quote these as examples of mice homozygous in yellow.

(*b*) The total number of offspring is 72 yellow and 41 other colour. On the theory that yellow-bearing gametes do not conjugate, one would expect the ratio 3 : 1, from which the calculated result of the above matings would be 84·75 : 28·25, a very poor approximation indeed. On the alternative theory that the yellow-bearing gametes do actually conjugate but that the zygotes so produced perish before birth, one would expect the ratio 2 : 1, from which the calculated result would be 75·3 : 37·6, a very close approximation to the experimental figures. The latter suggestion, moreover, harmonises with the

combined results of Cuénot, Castle, and Durham. Adding my own results to those of the other observers named, we find:—

	Yellow.	Other colour.
Cuénot	263	100
Castle (1910)	800	435
Durham (1911)	448	232
Laurie	72	41
Experimental	1583	808
Calculated 2 : 1	1594	797

It is of interest to find this anomalous result confirmed from experiments with an additional independent strain of mice.

(*c*) The number of young in a litter from yellow × yellow which survive to an age at which their colour is determinable is small, averaging only 3·64, as against 4·58 among mice of other colours. It is possible that this is associated with the hypothetical abortion of zygotes homozygous in yellow. Cuénot and Castle find a similar though smaller difference in size of family; but, on the other hand, Durham does not. (See Appendix A.).

II. The table on pp. 168 and 169 shows a list of matings of yellow × other colour. One notes:

(*a*) The 54 matings of yellow × other colour give 131 yellow: 125 other coloured young, expectation being, on the supposition that all the yellows were heterozygous, 128: 128.

(*b*) There were 36 yellow mice involved in the matings, of which 11 were known from their parentage to be heterozygous. The remaining 25 were derived from yellow × yellow, and one-third at least of these should have been gametically pure to yellow and have given only yellow young when mated to mice of any other colour. But all save one, and this had a couple of youngsters only, threw some other colour in addition to yellow.

(*c*) Of the 25 yellow mice ex yellow × yellow 14 are recorded also in the list of matings of yellow × yellow, so that 11 remain to be added to the 26 of the other list, making 37 yellow mice of which both parents were yellow, and of which none, on being tested adequately, proved to be homozygous, though about a dozen should have been so, even assuming both the yellow parents to have been in each case heterozygous.

(*d*) The number of young in a litter from yellow × other colour which survived to an age at which their colour was determinable averages 4·74, much the same as in the case of matings in which both parents are some colour other than yellow, where the average is 4·58. There is no reason associated with the theory of abortion of zygotes Y Y why this should be otherwise. There is, of course, no opportunity for the formation of such zygotes in the mating of yellow × other colour.

Yellow × Other Colour	Yellow	Golden-agouti	Cinnamon-agouti	Black, *i.e.*, dense black	Blue, *i.e.*, dilute black	Chocolate, *i.e.*, dense chocolate	Silver-fawn, *i.e.*, dilute chocolate	Total
Yellow × Black								
43 ♀ (ex yel. × yel.) × 47 ♂	2	—	—	2	—	—	—	4
Yellow × Blue								
45 ♂ (ex yel. × yel.) × 38 ♀	3 (77 ♀ : 78 ♀ : 79 ♂)	—	—	—	2	—	—	5
45 ♂ (,, ,, ,,) × 80 ♀	2	—	—	1	2	—	—	5
334 ♂ (,, ,, ,,) × 165 ♀	2	—	—	1	—	1	—	4
334 ♂ (,, ,, ,,) × 487 ♀	1	—	—	1	—	2	—	4
269 ♂ (,, ,, ,,) × 247 ♀	3	—	—	1	—	1	—	5
77 ♀ (,, ,, × blue) × 537 ♂	1	—	—	—	1	—	—	2
78 ♀ (,, ,, ,,) × 268 ♂	1	—	—	—	3	—	—	4
78 ♀ (,, ,, ,,) × 533 ♂	2	—	—	—	—	—	—	2
78 ♀ (,, ,, ,,) × 981 ♂	1	—	—	—	6	—	—	7
79 ♂ (,, ,, ,,) × 184 ♀	2	—	—	3	—	1	—	6
Yellow × Chocolate								
15 ♂ (ex yel. × yel.) × 95 ♀	2 (234 ♂ : 235 ♂)	—	—	1	—	—	—	3
15 ♂ (,, ,, ,,) × 112 ♀	5	—	—	1	—	—	—	6
18 ♀ (,, ,, ,,) × 55 ♂	1	—	—	1	—	—	—	2
45 ♂ (,, ,, ,,) × 41 ♀	2	—	—	3	—	—	—	5
49 ♂ (,, ,, ,,) × 94 ♀	3 (395 ♀ : 396 ♀)	—	—	2	—	—	—	5
44 ♀ (,, ,, ,,) × 39 ♂	5 (85 ♀ : 87 ♀ : 83 ♂)	—	—	—	—	1	—	6
334 ♂ (,, ,, ,,) × 51 ♀	3	—	—	—	—	2	—	5
159 ♂ (,, ,, ,,) × 127 ♀	3	—	—	—	—	3	—	6
269 ♂ (,, ,, ,,) × 283 ♀	1	—	—	—	—	2	—	3
269 ♂ (,, ,, ,,) × 326 ♀	1	—	—	—	—	4	—	5
270 ♂ (,, ,, ,,) × 274 ♀	2 (506 ♂)	—	—	—	—	1	—	3
271 ♂ (,, ,, ,,) × 285 ♀	1	—	—	—	—	1	—	2
271 ♂ (,, ,, ,,) × 286 ♀	2	—	—	—	—	—	—	2
271 ♂ (,, ,, ,,) × 287 ♀	—	—	—	—	—	2	—	2

Yellow Chocolate								
272 ♂ (ex yel. × yel.) × 277 ♀	5	—	—	—	—	1	—	6
67 ♂ (,, ,, ,,) × 52 ♀	1 (383 ♀)	—	—	1	—	5	—	7
69 ♂ (,, ,, ,,) × 98 ♀	1	—	—	2	—	1	—	4
890 ♂ (,, ,, ,,) × 834 ♀	4	—	—	1	—	2	—	7
335 ♂ (,, ,, ,,) × 175 ♀	2 (521 ♀ : 522 ♂)	—	—	—	—	—	—	2
72 ♀ (,, ,, choc.) × 55 ♂	5	—	—	1	—	—	—	6
1364 ♂ (,, ,, cin.-ag.) × 1365 ♀	—	—	—	1	1	2	—	4
1025 ♂ (,, ,, sil.-fawn) × 1024 ♀	2	—	—	1	—	1	—	4
78 ♀ (,, ,, blue) × 92 ♂	4	—	—	1	—	—	—	5
Yellow × Silver-fawn								
494 ♂ (ex yel. × yel.) × 167 ♀	2	—	3	—	—	—	—	5
494 ♂ (,, ,, ,,) × 182 ♀	2 (1088 ♀)	—	4	—	—	—	—	6
1053 ♀ (,, ,, ,,) × 1052 ♂	7	—	—	1	—	—	—	8
1054 ♀ (,, ,, ,,) × 1052 ♂	5	—	—	1	—	—	—	6
824 ♀ (,, ,, ,,) × 829 ♂	4	—	—	1	—	2	—	7
891 ♂ (,, ,, ,,) × 831 ♀	2	—	—	1	—	1	—	4
891 ♂ (,, ,, ,,) × 832 ♀	3	—	—	2	—	1	—	6
413 ♀ (,, ,, ,,) × 481 ♂	4 (1025 ♂ : 1026 ♀)	—	—	—	—	2	—	6
68 ♀ (,, ,, ,,) × 548 ♂	2	—	—	—	—	2	—	4
820 ♂ (,, ,, ,,) × 838 ♀	2	—	—	—	—	3	—	5
820 ♂ (,, ,, ,,) × 840 ♀	3	—	—	—	—	3	—	6
821 ♀ (,, ,, ,,) × 843 ♂	2	—	—	—	—	3	—	5
77 ♀ (ex yel. × blue) × 547 ♂	2 (1040 ♂ : 1047 ♀)	—	—	2	2	—	—	6
78 ♀ (,, ,, ,,) × 545 ♂	2	—	—	—	2	—	—	4
79 ♂ (,, ,, ,,) × 182 ♀	3 (473 ♂ : 474 ♀)	—	—	1	—	1	—	5
1047 ♀ (,, ,, sil-fawn) × 547 ♂	2	—	—	—	2	2	—	6
385 ♀ (,, ,, choc.) × 549 ♂	2	—	—	—	—	4	—	6
393 ♀ (,, ,, ,,) × 550 ♂	3	—	—	—	—	—	—	3
396 ♀ (,, ,, ,,) × 550 ♂	2	—	—	—	—	3	—	5
Yellow × Cinnamon-agouti								
1088 ♀ (ex yel. × sil.-fawn) × 1256 ♂	2 (1364 ♂)	—	2	—	—	1	—	5
Observed . . .	131	—	9	34	21	61	—	256
		125						
Calculated . . .	128	128						

Some of the yellow mice were mated with albinos, as I wished to discover and eliminate strains carrying albinism. These matings were thus incidental, but may nevertheless be put on record as follows:—

Yellow × Albino	Yellow	Black, *i.e.*, dense black	Blue, *i.e.*, dilute black	Chocolate, *i.e.*, dense chocolate	Silver-fawn, *i.e.*, dilute chocolate	Albino	Total
♂ × ♀	—	2	—	—	—	2	4
♂ × ♀	—	1	—	—	—	1	2
♂ × ♀	1	2	—	—	—	4	7
♂ × ♀	—	2	—	—	—	5	7
♀ × ♂	—	1	—	—	—	1	2
♀ × ♂	2	2	1	—	—	1	6
	3	10	1	—	—	14	28
♂ × ♀	2	2	—	2	—	—	6
♂ × ♀	4	2	—	—	—	—	6
♂ × ♀	—	—	—	2	—	—	2
♂ × ♀	1	1	—	3	—	—	5
♂ × ♀	3	2	—	2	—	—	7
♂ × ♀	1	1	—	1	—	—	3
♂ × ♀	1	4	—	—	—	—	5
♂ × ♀	4	1	—	—	—	—	5
♂ × ♀	2	—	—	2	—	—	4
♂ × ♀	2	1	—	—	—	—	3
♂ × ♀	4	—	—	1	—	—	5
♂ × ♀	2	—	—	3	—	—	5
♂ × ♀	—	—	—	1	—	—	1
♂ × ♀	5	—	—	—	—	—	5
♀ × ♂	2	2	1	—	1	—	6
♀ × ♂	—	1	1	2	—	—	4
♀ × ♂	4	3	—	—	—	—	7
♀ × ♂	3	2	—	—	—	—	5
♀ × ♂	2	1	—	—	—	—	3
Observed	45	33	3	19	1	14	115
		56					
Calculated	50·5	50·5					

It does not appear necessary to discuss the above matings individually, but one notes:—

(*a*) In those litters where albinos are present the proportions of coloured and albino young agree with expectation. Equality is expected, the numbers are 14 : 14.

(*b*) Among the coloured offspring 45 are yellow and 56 other colour, expectation being equality since all the yellow parents are known to be heterozygous either from their parentage or from some other mating.

General Results of the Present Experiments on the Heredity of Yellow Coat Colour in Mice.

Firstly, to confirm in a different strain of mice the evidence that yellow mice occur only in the heterozygous condition; and secondly, to support the view that in the mating yellow × yellow, zygotes of the formula Y Y are actually formed, but are abortive.

B. *Dense and Dilute Colourations.*

Each colour in the epistatic series has its dense and dilute form, density and dilution forming an allelomorphic pair. Density may be thought of as due to the presence of a factor D and dilution as due to the absence of this factor. My investigations concern the dense and dilute forms of black and chocolate.

I was led to investigate this matter through the appearance, recorded in my 1908 report, of black, blue, and chocolate young in a litter from the mating of two blacks, and the fact that a particular yellow mouse threw blacks when mated with chocolate, and blues when mated with blue. While working the matter out, Miss Durham's account (1908) of similar experiments appeared. The details I now publish confirm her work, while showing that Cuénot's suggestion that chocolate is the dilute form of black is untenable. I am able to add some further types of crosses to those recorded by Durham, which give the expected results.

Evidence against Cuénot's suggestion that chocolate is the dilute form of black and in favour of the view:—

a. That chocolate carries the factor for dense deposition of pigment, and that silver-fawn is the condition of chocolate in which this factor is absent;

b. That black carries the factor for dense deposition of pigment, and that blue is the condition of black in which this factor is absent.

Black and chocolate are the two lowest terms in the epistatic colour series.

Chocolate homozygous (DD bb) × *blue homozygous (dd BB).*

F_1 black (Dd Bb).

F_2 15 black	: 4 blue	: 3 choc.	: 1 sil.-fawn	
1	1	1	0	ex pair blacks of unknown parentage.
16	5	4	1	
44	17	17	8	Durham.
60	22	21	9	observed.
63	21	21	7	calculated 9 . 3 . 3 . 1 ratio.

Black homozygous (DD BB) × *silver-fawn (dd bb).*

F_1 black (Dd Bb).

F_2 5 black	: 2 blue	: 3 choc.	: 1 sil.-fawn	
67	21	20	5	Durham.
72	23	23	6	observed.
69·75	23·25	23·25	7·75	calculated 9 . 3 . 3 . 1 ratio.

The above two types of di-hybrid matings substantiate the view above stated. Further matings, all in harmony with this view, are:

Black carrying silver-fawn (Dd Bb) × *silver-fawn (dd bb).*

F_1 2 black	: 1 blue	: 0 choc.	: 2 sil.-fawn	observed.
1·25	1·25	1·25	1·25	calculated 1 . 1 . 1 . 1 ratio

Black carrying blue (Dd BB) × silver-fawn (dd bb).

F_1	1 black :	4 blue	observed.
	2·5	2·5	calculated 1 . 1 ratio.

Black carrying chocolate (DD Bb) × silver-fawn (dd bb).

F_1	14 black :	10 chocolate	observed.
	12	12	calculated 1 . 1 ratio.

Black carrying blue (Dd BB) × black carrying silver-fawn (Dd Bb).

F_1	2 black :	1 blue	observed.
	2·25	0·75	calculated 3 . 1 ratio.

Black carrying blue (Dd BB) × black carrying chocolate (DD Bb).

F_1	4 blacks	observed.
	4	calculated.

Black × chocolate.

Black homozygous (DD BB) × chocolate homozygous (DD bb).
F_1 black (DD Bb).

F_2	16 black :	7 chocolate	
	42	17	Durham.
	58	24	observed.
	61·5	20·5	calculated 3·1 ratio.

Black homozygous (DD BB) × black carrying chocolate (DD Bb).
F_1 black. Four matings gave 16 black young.

Black carrying chocolate (DD Bb) × chocolate homozygous (DD bb).

F_1	4 black :	4 chocolate	observed.
	4	4	calculated 1 . 1 ratio.

Black × blue.

No matings DD BB × dd BB, but F_1 from black (DD BB) × black carrying blue (Dd BB) gave 16 black young as the result of three matings.

F_2. None of the F_1 generation were mated, but the following results of matings between blacks unconnected with the above are such as would be expected if both blacks carried blue (Dd BB).

Dd BB	Dd BB				
33 ♂	× 35 ♀	gave	5 black :	2 blue.	
33 ♂	× 35 ♀	,,	3	1	
33 ♂	× 36 ♀	,,	7	2	
26 ♂	× 23 ♀	,,	1	1	
			16	6	
			50	13	Durham, F_2 from black × blue.
			66	19	observed.
			63·75	21·25	calculated 3 . 1 ratio.

Chocolate × silver-fawn.

Chocolate homozygous (DD bb) × silver-fawn (dd bb).
F_1 chocolate (Dd bb).

F_2	14 chocolate :	7 silver-fawn.	
	3	1	ex pair chocs. of unknown parentage.
	17	8	observed.
	18·75	6·25	calculated 3 . 1 ratio.

Durham did not carry any mating of the above type into the F_2 generation.

Chocolate carrying silver-fawn (Dd bb) × silver-fawn (dd bb).

F_1	7 chocolate :	10 silver-fawn	observed.
	8·5	8·5	calculated 1 . 1 ratio.

Blue × silver-fawn.

No matings dd BB × dd bb. But, as above recorded, a black carrying blue (Dd BB) × silver-fawn (dd bb) gave black and blue in F_1.

F_2 from these F_1 blues (dd Bb):

2 blues :	2 silver-fawns.	
4	1	ex pair blues of unknown parentage.
6	3	
46	17	Durham.
52	20	observed.
54	18	calculated 3 . 1 ratio.

Silver-fawn × silver-fawn.

Silver-fawns should breed true, since they represent the lowest term of the epistatic colour series associated with absence of factor for dense deposition of pigment. Zygotic formula dd bb.

Five matings between silver-fawns gave 28 silver-fawn young.

APPENDIX A.

Average Number of Young in Litter.

Durham's data are included for comparison; each of her averages is based on at least 75 litters.

		Average per litter Laurie	Durham
Yellow	× yellow	3·64 (31 litters)	3·90
Yellow	× other colour	4·74 (54 „)	3·97
Agouti	× agouti		3·47
Agouti	× other colour (not yellow)		3·32
Black	× black	4·83 (23 „)	4·60
Black	× other colour (not yellow)	4·29 (14 „)	3·99
Blue	× blue	4·24 (21 „)	
Blue	× other colour (not yellow)	5·12 (26 „)	
Chocolate	× chocolate	4·32 (25 „)	3·96
Chocolate	× other colour (not yellow)	4·71 (34 „)	3·93
Silver-fawn	× silver-fawn	5·60 (5 „)	
Silver-fawn	× other colour (not yellow)	4·79 (14 „)	
Albino	× albino	5·18 (17 „)	
Albino	× yellow	4·60 (25 „)	
Albino	× colour (not yellow)	4·19 (41 „)	4·27

In the above records, both Miss Durham's and my own, only those mice are counted which lived long enough for their colours to be determined.

The strikingly smaller size in my experiments of the average litter ex yellow × yellow, as compared with the other matings, is commented on above. A lesser difference was observed by Cuénot also (yellow × yellow 3·38; yellow × other colour 3·74) and Castle (yellow × yellow 4·71; yellow × other colour 5·57). On the other hand, Durham's figures warn one to be cautious as to one's inferences.

The data from which the above averages are calculated are as follows:—

Yellow × yellow. See list.
Yellow × other colour. See list.
Black × black gave 7, 5, 3, 6, 7, 9, 4, 2, 8, 4, 2, 5, 4, 4, 4, 3, 2, 6, 5, 7, 7, 3, 4.
Black × blue gave 3.
Black × chocolate gave 2, 2, 4, 2.
Black × silver-fawn gave 5, 6, 6, 8, 4, 6, 2, 5, 5.
Blue × blue gave 7, 4, 4, 7, 2, 4, 3, 6, 3, 2, 3, 5, 4, 6, 5, 4, 3, 8, 2, 2, 5.
Blue × chocolate gave 5, 7, 5, 2, 7, 5, 6, 5, 4, 4, 7, 8, 7, 4, 3, 5, 2, 4, 6, 7, 4, 7, 3, 6, 7.
Blue × black. See black × blue.
Chocolate × chocolate 7, 4, 5, 3, 5, 3, 1, 2, 2, 2, 5, 6, 6, 5, 6, 2, 2, 5, 6, 6, 4, 6, 7, 3, 5.
Chocolate × silver-fawn gave 5, 3, 1, 7, 4.
Chocolate × blue. See blue × chocolate.
Chocolate × black. See black × chocolate.
Silver-fawn × silver-fawn gave 7, 3, 6, 6, 6.
Silver-fawn × black. See black × silver-fawn.
Silver-fawn × chocolate. See chocolate × silver-fawn.
Albino × albino gave 5, 2, 4, 6, 6, 5, 6, 4, 5, 6, 5, 4, 6, 7, 6, 5, 6.
Albino × yellow gave 6, 1, 4, 5, 6, 6, 4, 5, 7, 6, 7, 5, 5, 3, 3, 5, 5, 5, 4, 2, 7, 3, 7, 2, 2.
Albino × colour other than yellow gave 4, 3, 4, 1, 7, 2, 4, 7, 5, 8, 6, 5, 6, 4, 4, 7, 5, 6, 3, 3, 2, 4, 1, 2, 2, 2, 4, 8, 4, 2, 5, 6, 3, 4, 5, 5, 6, 2, 5, 4, 2.

APPENDIX B.

Albino Mice.

I crossed many of my mice with albinos in the process of testing their genetic behaviour. There appears to be no need to set out the results in detail, but the following points may be noted:—

The size of litter in the three types of mating—albino × albino, albino × yellow, and albino × colour other than yellow—is given in Appendix A.

The colour composition of the litters from albino × colour conformed to the rules now well established for the heredity of albinism in mice.

Fourteen of the matings albino × colour yielded some albino young; the total young from these matings numbered 37 albino : 30 coloured, expectation being equality.

APPENDIX C.

Piebald Mice.

A piebald chocolate-and-white mouse appeared in a litter born to a chocolate mouse bought in kindle from a dealer. I bred from it to the F_2 generation in order to assure myself that it acted as a recessive to self-colour.

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The Question of Fatigue from the Economic Standpoint.—Interim Report of the Committee, consisting of Professor J. H. MUIRHEAD (*Chairman*), Miss B. L. HUTCHINS (*Secretary*), Miss A. M. ANDERSON, Professor BAINBRIDGE, Mr. E. CADBURY, Mr. P. SARGANT FLORENCE, Professor STANLEY KENT, Mr. W. T. LAYTON, Dr. T. G. MAITLAND, Miss M. C. MATHESON, Dr. C. S. MYERS, Mr. J. W. RAMSBOTTOM, *and* Dr. J. JENKINS ROBB. *In addition, help has been kindly afforded by the following:* Miss MABEL ATKINSON, Dr. WM. BROWN, Mr. ARTHUR GREENWOOD, *and* Dr. UDNEY YULE.

THE Committee has met four times, and has made a preliminary survey of the subject of investigation, and has discussed the matter at some length.

An extensive Bibliography of Fatigue has been prepared for the use of the Committee by Miss B. L. Hutchins.

A short report has been drawn up on industrial experiments in shortening hours, also by Miss Hutchins.

Some notes have been kindly contributed by Dr. William Brown on the existing state of psychological knowledge in regard to fatigue.

A Memorandum on the provisional aims and methods of the inquiry has been drawn up by Mr. Ramsbottom, and adopted by the Committee as a basis of its future work.

As a result of our preliminary survey, we have become aware that a considerable amount of work on the subject has been done in America and on the Continent of Europe, and, so far, comparatively little in this country.

We consider, however, that but little definite information exists, and detailed scientific investigation is badly needed, especially in view of the rapid development of the factory industry and the progressive urbanisation of the working class in this country.

We propose, if reappointed, to adopt the following method of investigation:—

Mr. Ramsbottom has defined the object of inquiry as being 'to

ascertain the effect on physique, accident occurrence, production and general social well-being of present conditions relating to fatigue occurrence in industrial work, and to discuss possible improvements therein, and the best methods of obtaining them.' We concur with this definition.

We hope that Dr. Maitland, being a member of our Committee, will prepare a short résumé of existing knowledge on the effects of muscular and mental fatigue respectively. We shall also endeavour to ascertain what are the main subjective and objective determinants of fatigue; *e.g.*, what is the relative importance of muscular work, mental strain, monotony, atmospheric wet-bulb temperature (kata-thermometric condition), noise, light, etc.; and to discover some reliable physiological quantitative index of fatigue, and the chief physiological effects of over-fatigue.

We shall consider the questions what increase, if any, has occurred in general morbidity in recent years, and to what extent this can be ascribed to industrial fatigue; and what difference can be traced between the morbidity cases of workers in various age groups from fifteen upwards engaged in occupations involving long hours of work or specially fatiguing conditions, and those for all workers or workers in fairly easy occupations.

We shall also consider the incidence of industrial accidents in relation to hours of work; and the variation in the output of work per hour during the day, and the output per day with various lengths of working-day.

We propose to give special attention to the speeding-up of machinery, and to inquire how far this has been accompanied by a reduction of hours.

We shall also consider the probable social reactions of over-fatigue, and what general remedies, if any, may seem most promising and hopeful.

The Committee has made a preliminary division of the work, as so sketched, among the following sub-committees:—

Physiological and Psychological.	*Industrial.*	*Statistical.*
Dr. Maitland (*Convener*).	Miss Anderson.	Mr. Layton (*Convener*).
Prof. Muirhead.	Mr. Cadbury.	Miss Hutchins.
Dr. Myers.	Mr. Florence (*Convener*).	Mr. Ramsbottom.
Dr. Bainbridge.	Miss Hutchins.	Dr. Yule.
Dr. Legge.	Miss Matheson.	
	Mr. Ramsbottom.	

And we have appointed Mr. Ramsbottom as hon. organising secretary.

For purposes of the foregoing inquiries we think it will be essential to obtain the services of expert and paid assistants.

The Committee ask to be reappointed, with the addition of the words 'social and' before 'economic,' in their terms of reference, and to be allotted a grant.

Gaseous Explosions.—Seventh Report of the Committee, consisting of Dr. DUGALD CLERK (*Chairman*), Professor DALBY (*Secretary*), *and* Professors W. A. BONE, F. W. BURSTALL, H. L. CALLENDAR, E. G. COKER, H. B. DIXON, Drs. R. T. GLAZEBROOK *and* J. A. HARKER, Colonel H. C. L. HOLDEN, Professors B. HOPKINSON *and* J. E. PETAVEL, Captain H. RIALL SANKEY, Professors A. SMITHELLS *and* W. WATSON, Mr. D. L. CHAPMAN *and* Mr. H. E. WIMPERIS.

THE decease of the Chairman, Sir William Preece, was reported to the Committee in December last, when a letter of condolence was sent to the family.

Sir William Preece had associated himself intimately with the investigations carried out by the Committee, and contributed an interesting Note on the Kinetic Theory of Gases. As Chairman he did much to help forward the important work on which the Committee is engaged both by his valuable suggestions and by his tactfulness and resource. His loss is not only deeply deplored, but felt to be a personal one by every member of the Committee.

The Vice-Chairman, Dr. DUGALD CLERK, was unanimously elected Chairman.

The Committee met three times during the session 1913-14 at the City and Guilds (Engineering) College, Exhibition Road, London, S.W. The following Notes were presented and discussed:—

Note 32 by Professor DALBY on Suction Temperatures directly measured and deductions therefrom, together with a summary of a series of seventeen experiments made at the City and Guilds (Engineering) College on a Crossley gas-engine with a cylinder seven inches in diameter, stroke fourteen inches, and with a compression ratio at 4·8.

Note 33 by Mr. H. E. WIMPERIS on Thermal Efficiency.

Note 34 by Professor E. G. COKER and Mr. W. A. SCOBLE on Temperature Distribution in the Cylinder of a Gas-engine.

Note 35 by Professor W. WATSON on the Spectroscopic Study of the Combustion of Air-petrol Mixtures.

The object of Note 32 was to show how the suction temperature varied with the speed, with the jacket temperature, and with the mixture. The records given in the Note relate to trials Nos. 72 to 90. The data were obtained by a research student of the City and Guilds (Engineering) College, Mr. Limbourne, working under the supervision of Professor Dalby. A table included in the Note shows the variation in the suction temperatures, and a set of curves, also included, gives the temperatures of the working mixture; these indicate how the direct knowledge of the suction temperature can be applied to determine the temperatures at other parts of the cycle.

In Note 33 Mr. Wimperis discusses the thermal efficiency of an engine using as the working agent a standard gas referred to in the first

report of the Committee, and using in his calculations the values of the internal energy defined by the curve in fig. 6 of that report.

In Note 34 Professor Coker describes the method of measuring the cyclical temperature in a gas-engine cylinder used by him at the Technical College, Finsbury, and gives the results of some recent experiments. Curves are included showing the temperature of the explosive charge, together with tables of the actual temperatures at various points in the cycle. A full description of the thermo-couple used in these experiments is given in the Note.

In connexion with Note 35 Professor Watson showed a series of photographs of the spectrum of the light given by the burning charge in the cylinder of a petrol engine. The results show that the gases in the cylinder continue to emit light giving a line spectrum for a considerable time after the chemical changes are generally assumed to have been completed.

Before proceeding to consider the work carried out during the current session it has been thought advisable to give a brief summary of the previous reports of the Committee.

Summary of Previous Reports.

The first report is devoted mainly to the subject of the specific heats of gases at high temperatures. The constant-pressure experiments of Wiedemann, Regnault, Holborn, and Henning are analysed and discussed, and a curve is given showing the energy of CO_2, steam, and air in terms of the temperature Centigrade. The experiments of Dr. Dugald Clerk are described, and the results obtained compared with the constant-pressure experiments mentioned above. The closed vessel experiments of Mallard, Le Chatelier, and Langen are analysed and the results plotted and discussed.

The report ends with the discussion of thermal equilibrium, chemical equilibrium, the motion of a gas, and the measurement of temperature. A curve is given showing the internal energy of a gas-engine mixture in terms of the temperature.

There is an appendix by Professor Callendar on 'The Deviation of Actual Gases from the Ideal State,' and on 'Experimental Errors in the Determination of their Specific Heats.'

The second report is mainly devoted to the subject of the specific heat of gases at high temperatures. Regnault's results at low temperatures are discussed in the light of Mr. Swann's experiments, which were communicated to the Committee by Professor Callendar. The Committee definitely adopted Mr. Swann's values for air and for CO_2 as given below.

Volumetric heat of air at 100° C. is 19·8 lbs. per cubic foot,
" " CO_2 at 20° C. is 27·4 lbs. per cubic foot, and
at 100° C. is 30·7 lbs. per cubic foot.

The results of the experiments made by Dr. Dugald Clerk with the object of determining the volumetric heat of air at high temperature are given in the report, together with a description of Professor

Hopkinson's experiments on the compression of air in a gas-engine cylinder.

Dr. Watson's researches on the efficiency of a petrol motor are included in the report. Dr. Watson made a simultaneous measurement of the quantities of air and petrol taken into the engine and of the chemical composition of the exhaust gas. The point brought out was that the ratio of hydrogen to carbon in the exhaust gas was greater than the ratio of hydrogen to carbon in the petrol used. Additional evidence of this discrepancy is furnished by some experiments of Professor Hopkinson, and the experiments of Hopkinson and Watson are in agreement.

The report concludes with an account of the experiments on radiation carried out by Professor Hopkinson.

There are two appendices: one relating to Regnault's corrections in connection with the determination of the specific heat of air, and the other relating to Deville's experiments on the dissociation of gases by Dr. Harker.

The third report is devoted mainly to the consideration of the subject of radiation from gases. A brief general history of the subject is given, together with a record of the experiments of Professor Hopkinson and of Professor Callendar. The report discusses the direct effect of radiation on the efficiency of internal-combustion motors, the amount of radiation from flames, and the molecular theory of radiation from gases as well as the question of the transparency of flames to their own radiation. There is an appendix on the radiation of flames by Professor Callendar, giving some account of experiments made with a Mêker burner; a second appendix on the radiation in a gaseous explosion by Professor Hopkinson; and a third appendix which contains abstracts from various papers relating to the application of heat radiation from luminous flames to Siemens' Regenerating Furnaces.

The fourth report merely notes the number of meetings held during the year, and states that, partly owing to the breakdown of apparatus and partly to the demands made upon the time of the various investigators, only two notes were read; consequently it was decided that the work then on hand should be included in the report for the following year.

The fifth report continues the discussion of the effect of radiation, and is devoted mainly to the consideration of the factors which determine the heat flow from the gas to the walls of the cylinder. The remarkable effect of turbulence on the rate of combustion is first mentioned in this report. Particulars of Dr. Dugald Clerk's experiments are given, and these experiments definitely establish the fact that but for turbulence the speed at which modern internal-combustion engines are run would be impossible. Professor Hopkinson's experiments, in which a fan was placed inside a closed vessel and the rates of combustion observed with the fan at rest and in motion, are recorded in the report, and confirm Dr. Clerk's results.

In the sixth report the resignation of Dr. Dugald Clerk and Professor Hopkinson from the Joint Secretaryship of the Committee is

reported. Dr. Clerk consented, however, to act as Vice-Chairman, and Professor Dalby was appointed Secretary.

The Committee allocated the whole of the grant to the Secretary for the purpose of providing him with a permanent research assistant to carry on the work. It was stated that Professor Dalby and Dr. Clerk were engaged on the design of an experimental plant to be placed in the new laboratory of the City and Guilds (Engineering) College.

Six notes, relating chiefly to heat flow, temperature, and leakage, are briefly summarised.

Object of Present Report.

The following report is devoted partly to the special consideration of temperature measurements and subjects arising therefrom, and partly to the illustration of the use which can be made of the data obtained by the Committee.

Methods of Measuring Temperature of the Charge in a Gas-engine Cylinder under working conditions.

One of the problems requiring solution was the direct measurement of the temperature of the working agent in the cylinder while the engine was running under ordinary working conditions. The difficulty of making this measurement arises from the fact that during the

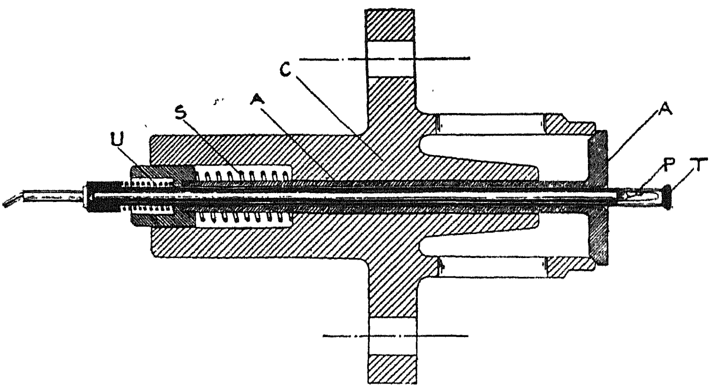


FIG. 1.

explosion of the charge in the engine cylinder the temperature is sometimes higher than that of the melting-point of platinum or of the couples which can be put in the cylinder to make the measurement.

In Note 32 is described a method devised by Professors Callendar and Dalby,[1] which for the first time enabled direct observation of the

[1] *Proc. Roy. Soc.*, A., vol. 80, 1907.

suction temperature to be made while the engine was working not only under normal conditions but under special conditions, during which the richest possible mixture was used and the temperature reached at explosion was considerably higher than that occurring in practice. The thermometer itself consisted of a piece of platinum wire about 0·7 inch long and $\frac{1}{1000}$ of an inch in diameter, arranged with compensating leads. It is placed in a thermometer-valve, which is inserted through the spindle of the admission-valve in the manner shown in fig. 1, in which P is the platinum thermometer, and T is the head of the thermometer-valve, which is inserted centrally in the

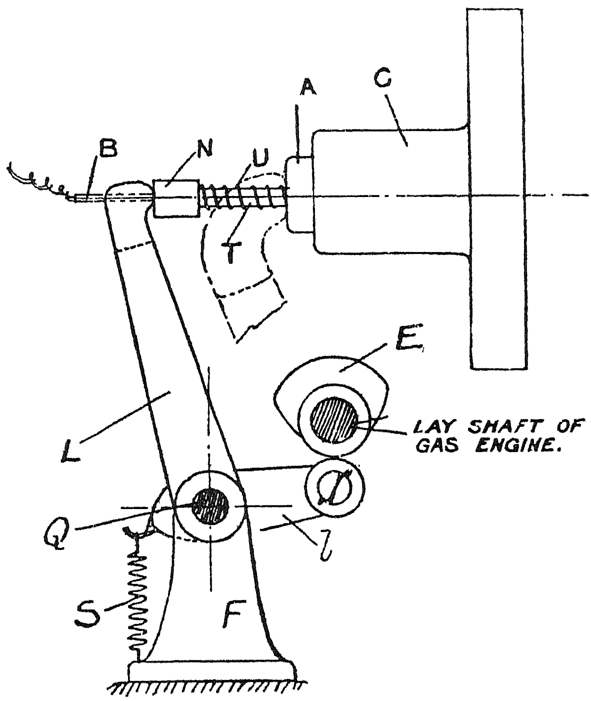


FIG. 2.

admission-valve A. The spring S serves to close the admission-valve, and the spring U serves to close the thermometer-valve. The main casting, C, carrying these valves is bolted to the engine in the ordinary way. A separate cam is mounted on the half-time shaft to operate the central thermometer-valve, and the complete arrangement is shown in fig. 2, where E is the cam; l and L are levers keyed to the supplementary shaft Q, which is carried on the casting F; the spring S maintains contact between the end of the lever l and the cam. The end of the thermometer with the leads projecting is shown at B. The lever L is in contact with the nut N on the thermometer-valve. The cam is so designed that during the explosion period the valve

is closed, and the thermometer therefore screened from the action of the gas. In this way the thermometer is withdrawn just before the end of compression, so that at this critical period of the cycle there is nothing in the shape of a protuberance to cause preignition. When the platinum thermometer is exposed in the cylinder and connected to the Wheatstone bridge and galvanometer on which the indications are received, the circuit is made by a contact-maker on the crank-shaft when the crank passes through an assigned crank-angle, and is broken by the contact-maker when the crank passes through a second assigned crank-angle a little greater than the first, so that the electrical

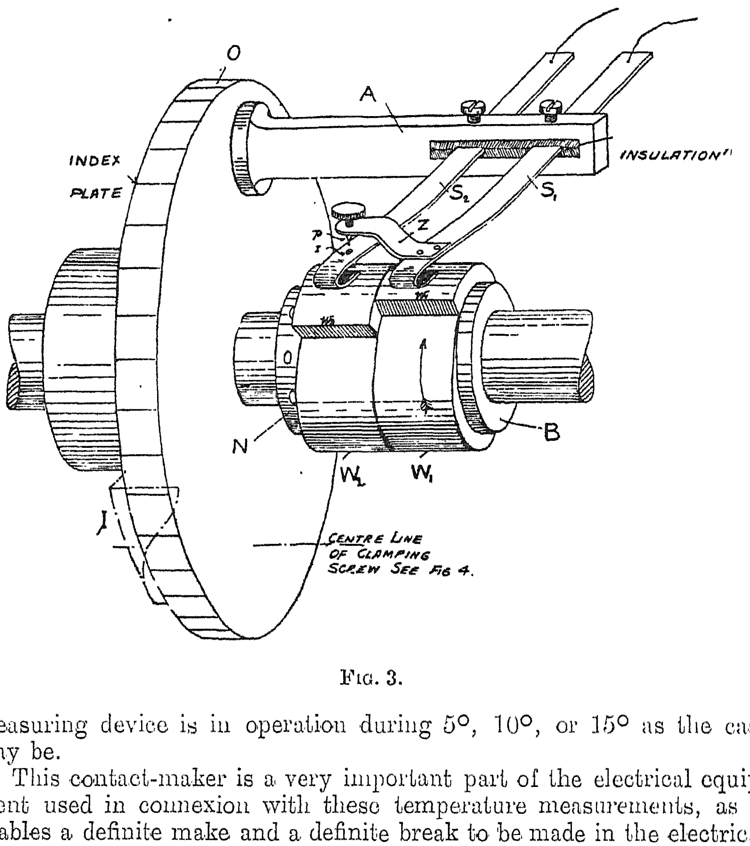


FIG. 3.

measuring device is in operation during 5°, 10°, or 15° as the case may be.

This contact-maker is a very important part of the electrical equipment used in connexion with these temperature measurements, as it enables a definite make and a definite break to be made in the electrical circuit, and, in addition, enables the time between the make and break to be adjusted with accuracy.

The contact-maker (fig. 3) consists of a brass bush B, keyed to a lay shaft of the engine, and carrying two fibre washers or cams W_1 and W_2, which can be clamped in any relative angular position against the flange of the bush by the nut N. A radial step, as u_1, is made in each washer, and the surface gradually rises from the bottom of the step to the normal circular surface of the washer. The reflexed ends

of the stiff springs S_1 and S_2 rest on the fibre cams. A projection Z carrying a platinum-pointed screw p is riveted to one of the springs, and the screw p is adjusted so that its point is just clear of the platinum rivet in the other spring when both springs are riding on the circular surfaces of their respective cams. Contact is made when the rotation of the lay shaft in the direction of the arrow brings the radial step w_1 of the cam W_1 under the spring S_1, thereby allowing it to fall down the step, thus bringing p and r together. Contact is broken when the radial step w_2 of the cam W_2 reaches the spring S_2, thereby allowing the second spring to fall down the step w_2. The epoch and duration of contact are readily adjusted by adjusting the angular positions of the cams relatively to the bush and also with regard to one another. The distances between the springs and the platinum contacts and the steps w are exaggerated in the diagram in order to make the principle of the apparatus clear. The percussion form of contact with platinum points is found to give definite and certain results. The contacts keep

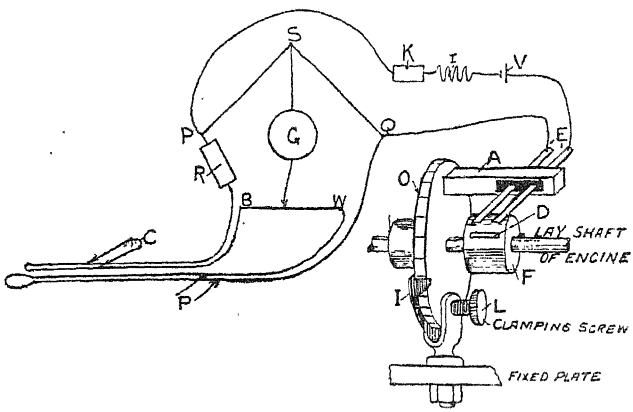


Fig. 4.

clean, and no trouble of any kind is experienced with them. The general arrangement of the electrical connections are shown in fig. 4. In this figure PS, QS are the equal ratio arms of the Wheatstone bridge. The galvanometer G is connected to the point S and to the sliding contact on the bridge-wire BW. The thermometer and its leads P are connected on one side of the bridge-wire, and the compensator C and the balancing resistance R on the other. The battery circuit includes a mercury reversing key K, an adjustable resistance r, and a storage cell V; and the battery is connected to the bridge at the points P and Q, and to the brushes of the periodic contact-maker at E. The brushes E are carried by an insulated arm A bolted to a divided disc O riding loosely on the lay shaft of the engine, and capable of being clamped in any position by the screw L. The index I shows the crank-angle corresponding to the middle point of the contact when the insulated copper strip D carried in the fibre bush F passes under the brushes.

The temperature is measured, therefore, during a particular crank-angle determined by the setting of the contact-maker. This can be set, while the engine is running, to determine the make and break at any assigned crank-angle in the revolution. It was usually set so that the interval between the make and break was 5° or 10°. In this manner the mean temperature over a small crank-angle can be measured at any point in the cycle, except only during the period of the explosions when the thermometer is withdrawn from the cylinder. But although there is this possibility with the method it is desirable to measure the temperature at a point on the cycle where the rate of change of temperature is at a minimum. This point occurs just after the closing of the suction-valve. The great advantage of making the measurement at this point is that the thermometer is exposed to the incoming charge during the whole of the suction-stroke and therefore the thermometer-valve tends to assume the temperature of the charge; consequently the temperature which the small wire is set to measure does not differ greatly from the temperature of the metal in which it is mounted. This condition tends to minimise the errors of measurement. At any other point in the cycle the rate of change of temperature is greater; and the error of the measurements, therefore, is likely to be greater owing to the lag of the thermometer. On the expansion-stroke, for example, the temperature may vary as much as 150° during the movement of the piston through $\frac{1}{10}$ of the stroke. Just after the closing of the suction-valve the variation of temperature during the movement of the piston through $\frac{1}{10}$ of the stroke is only about 20°.

Having found the temperature at one point in the cycle, the temperature at any other point can be calculated by using the charge itself as the thermometric agent. The characteristic equation of the charge is $\frac{PV}{T}=$ a constant. If, therefore, from the indicator diagram taken at the time the temperature was measured, the corresponding pressure and volume are measured, then the temperature at any other point of the cycle can be calculated by the aid of this constant and the pressure and volume scaled from the indicator diagram, allowance being made for chemical contraction of the charge after explosion. It is necessary to have accurate indicator diagrams from which to measure the pressure and volume for this purpose, and this has led to the development of an optical indicator.

Example of the Application of the Method to an Engine Trial (72) at the City and Guilds (Engineering) College.

The general procedure in making temperature measurements by this method, and with an improved optical indicator devised by Professor Dalby and Dr. Watson, may be illustrated by data obtained during a trial made at the City and Guilds (Engineering) College by Professor Dalby last year, a full report of which will be found in Note 32 communicated to the Committee.

Indicator Diagrams.

In each trial two indicator diagrams were taken—namely, a complete diagram showing the pressure and volume during the whole cycle, and a diagram taken with a thin disc stopped down so as to give on a large scale the portion of the diagram during the pumping-stroke. The diagrams are in general calibrated *in situ*.

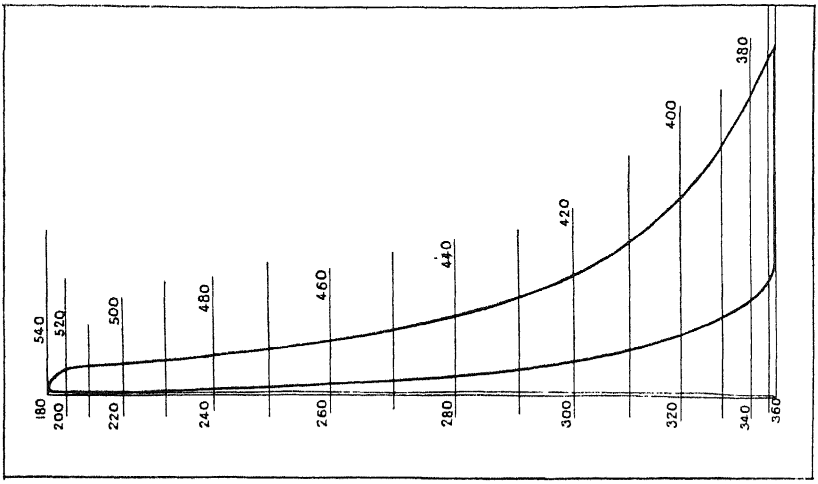


FIG. 5.

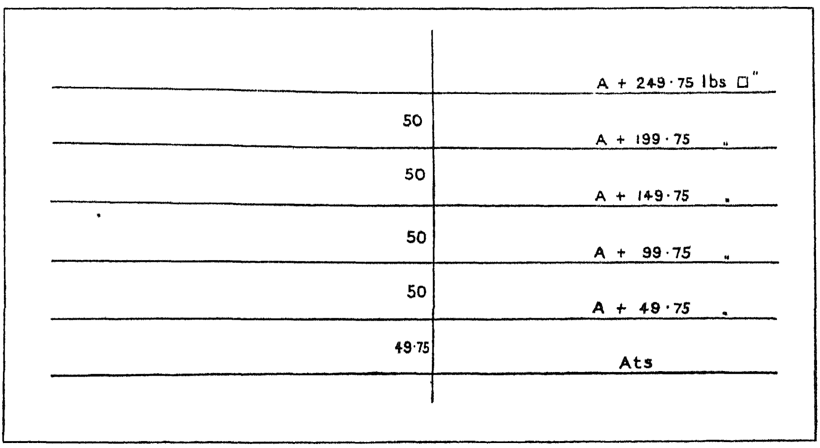


FIG. 6.

In carrying out a series of experiments, however, it was found that the scale was so constant that it was unnecessary to calibrate each diagram separately. The scale was therefore made for the two discs used, and was checked from time to time. A pair of typical diagrams

taken during trial No. 72, together with the scales, are shown in figs. 5, 6, 7, 8. The following data relate to trial No. 72:—

Mixture 6·88 air to 1 gas by volume.

Jacket temperature 29·5.

Temperature measured at crank-angle 200°; 77° C.

Pressure measured from the diagram at 200° crank-angle; 14·7 per square inch.

Volume measured at this point, 0·3872 cubic feet.

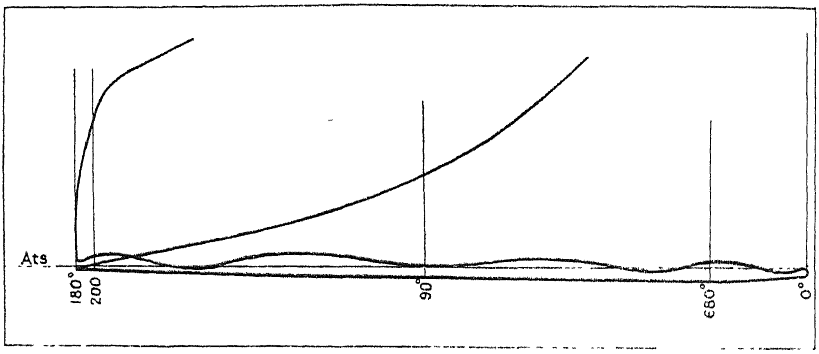


FIG. 7.

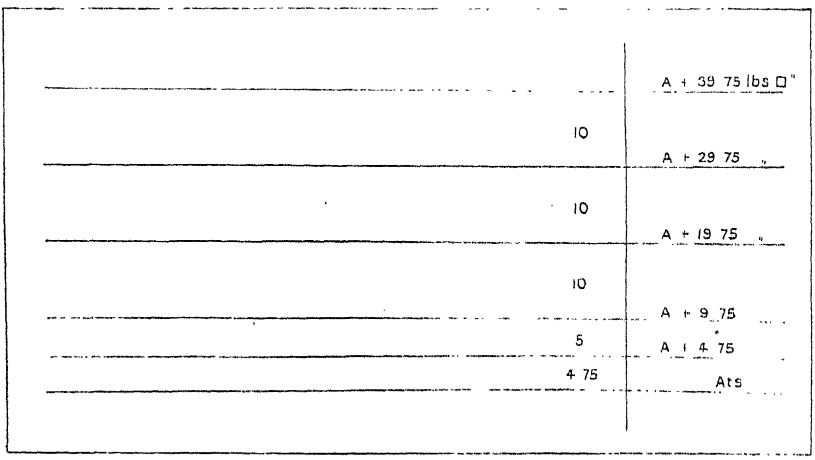


FIG. 8.

Speed 106 revolutions per minute.

The gas constant for the charge is therefore $\frac{PV}{T} = 0{\cdot}01616$.

This constant may now be used to calculate the temperature at any point along the compression-curve, since at a point where the pressure is P and the volume V, the temperature is:

$$T = \frac{PV}{\cdot 01616}.$$

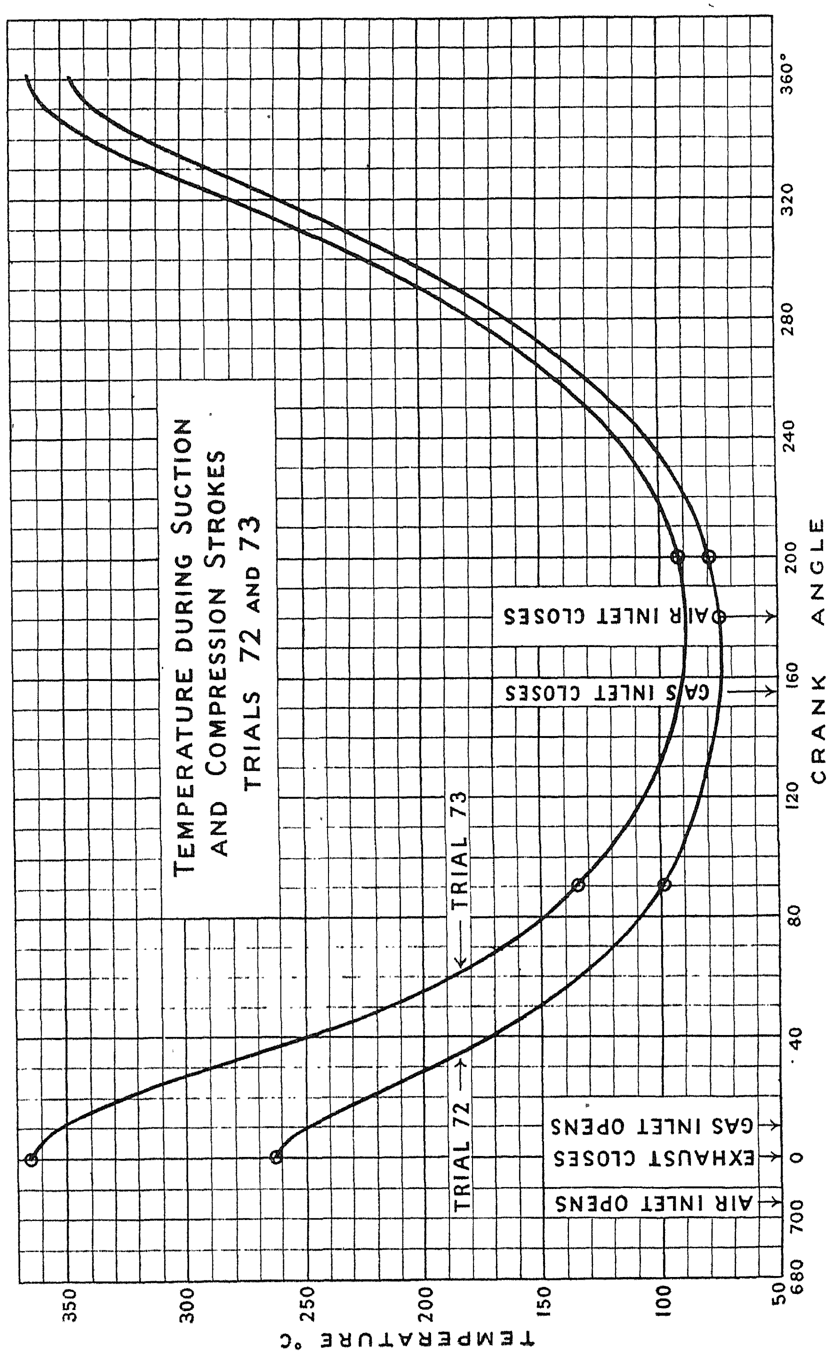

TEMPERATURE DURING SUCTION
AND COMPRESSION STROKES
TRIALS 72 AND 73
TRIAL 72
TRIAL 73
AIR INLET OPENS
EXHAUST CLOSES
GAS INLET OPENS
GAS INLET CLOSES
AIR INLET CLOSES
CRANK ANGLE
TEMPERATURE °C
680
700
0
40
80
120
160
200
240
280
320
360°
50
100
150
200
250
300
350

FIG. 9.

Fig. 9 shows temperature-curves for the compression stroke calculated in this way, both for trials 72 and 73. Trial 73 was run at about 200 r.p.m.

The constant, however, cannot be applied during the whole cycle, because, although the weight of the charge remains the same, assuming that there is no leak, yet the volume corresponding to this weight is slightly different after the explosion has taken place owing to the contraction due to the chemical rearrangement of the constituents. The chemical contraction is calculated from the analyses of the gases. In the gas used in the experiments referred to the contraction amounted to 3·14 per cent. The effect of this is to change the gas constant for all points along the expansion-curve from 0·01616 to 0·01565.

The curve, fig. 10, shows the temperatures calculated along the expansion-curves for trials 72 and 73.

When applying this method of taking the temperatures the governor should be put out of action, so that there shall be no change in the rate of the supply of gas which will produce a disturbance of the temperature in the cycle. Any disturbance produced in a particular cycle causes a temperature wave through a long series of succeeding cycles. In practice the gas-engine can be run without any difficulty without the governor if the engine is coupled to a generator, because the generator automatically settles down to the speed corresponding to the power applied to it, and by regulating the resistance of the armature or the fields, or both, the desired speed can be maintained for long periods. A special switch-board and a resistance-board have been designed for the engine at the City and Guilds (Engineering) College for the purpose of controlling the generator.

Method of Measuring the Temperature of the Charge by means of a Thermo-couple.

The second method of measuring the temperature of the charge in the cylinder is by means of a couple. This method has been developed by Dr. Coker and Mr. Scoble at the Technical College, Finsbury. It was found that alloys of platinum with rhodium and iridium respectively were able to withstand the temperature of explosion near the walls of the cylinder for some hours or even days when made into thermo-couples $\frac{5}{10000}$ to $\frac{8}{10000}$ of an inch thick, provided the engine was not overloaded. The actual temperature measurement is made by observing the change in the electromotive force produced in this couple by a change in temperature. The small changes in the electromotive force produced by a couple of this kind can be measured with great accuracy on the bridge described below.

The general relation between electromotive force and temperature found for one of the couples used is

$$E \text{ (microvolts)} = -174 + 7.6075T - 0.001673T^2.$$

The general arrangement of the apparatus is shown in fig. 11.

The battery B and resistances R_1 and R_2 are arranged in circuit so that the fall of potential between the extreme points of a bridge-

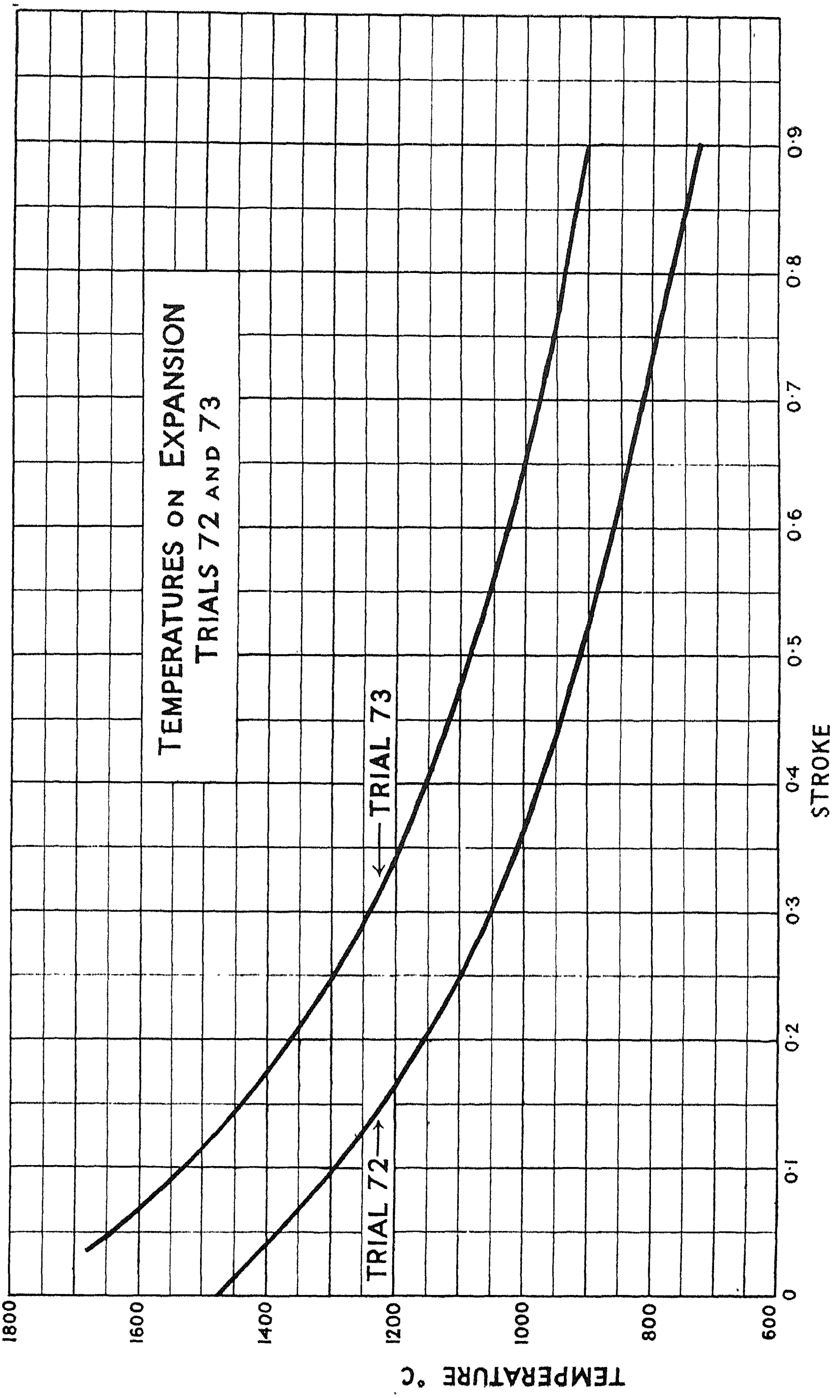

TEMPERATURES ON EXPANSION
TRIALS 72 AND 73
TRIAL 73
TRIAL 72
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
STROKE
1800
1600
1400
1200
1000
800
600
TEMPERATURE °C

Fig. 10.

wire, BW, can be adjusted to 1 millivolt. This is tested by the electromotive force of a cadmium cell, C, which can be opposed to the battery electromotive force by means of the upper key, K_1, an allowance for the known temperature variation of the electromotive force of the standard cell used being made by an adjustable contact-maker, D. The thermo-electric couple, H, has one lead connected to the lower key, K_2, and the other set to a set of resistances, S, in the main circuit, each of which gives a difference of potential of 1 millivolt when the

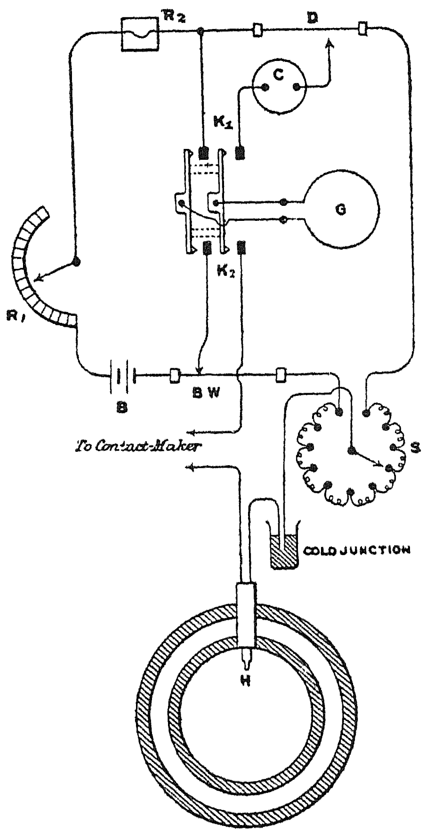


FIG. 11.—Thermo-Electric Bridge.

adjustments are correct. During an observation, therefore, the battery electromotive force opposes that of the couple and the readings of the bridge-wire and step resistance taken together measure the electromotive force of the couple when the galvanometer, G, shows a balance. The scale of the bridge-wire is graduated to read to 10 microvolts, and single microvolts may be read by estimation. The majority of the observations were taken when using a D'Arsonval galvanometer, giving, on a scale distant 110 centimetres, a deflection of 560 milli-

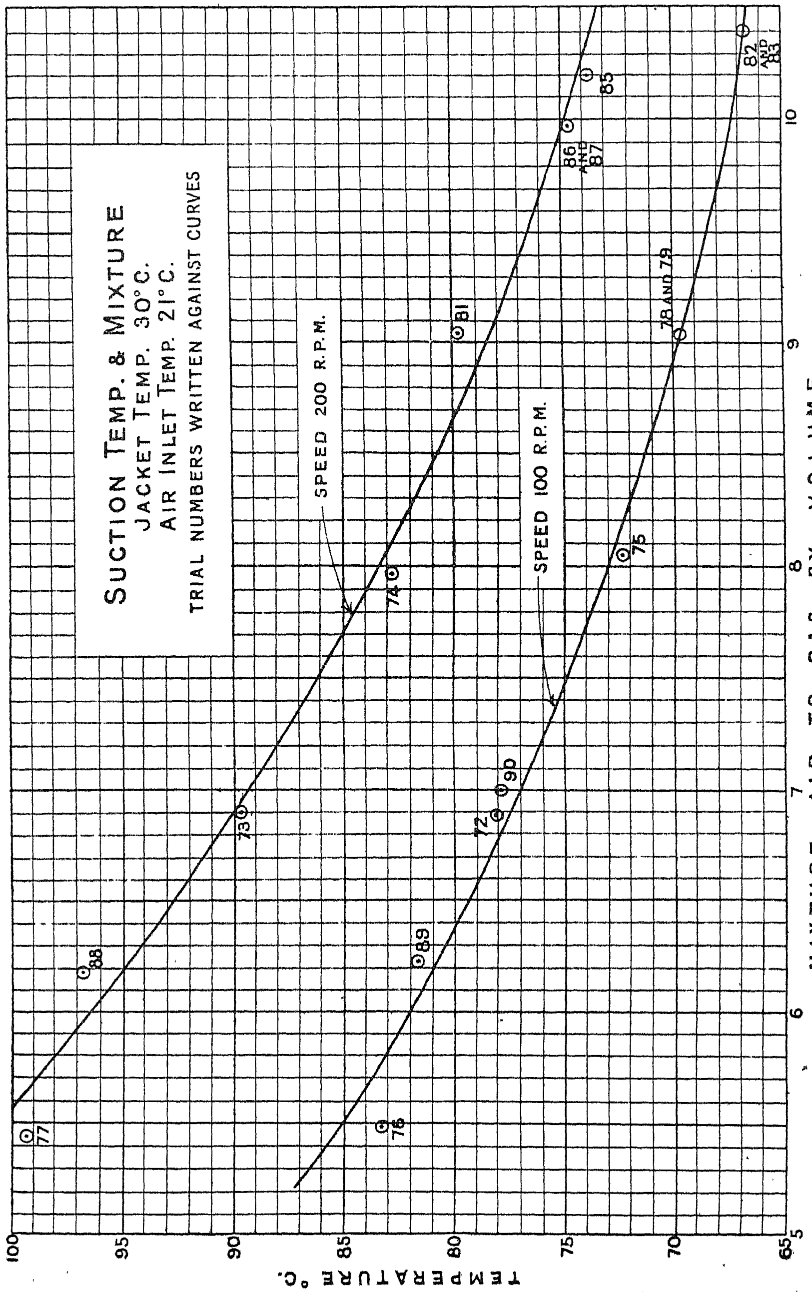

SUCTION TEMP. & MIXTURE
JACKET TEMP. 30° C.
AIR INLET TEMP. 21° C.
TRIAL NUMBERS WRITTEN AGAINST CURVES
SPEED 200 R.P.M.
SPEED 100 R.P.M.
MIXTURE AIR TO GAS BY VOLUME
TEMPERATURE °C.
5
6
7
8
9
10
100
95
90
85
80
75
70
65
77
88
73
74
81
86 AND 87
85
76
89
72
90
75
78 AND 79
82 AND 83

FIG. 12.

metres for 1 microvolt. The contact-maker used with this apparatus is one devised by Professors Callendar and Dalby, which has already been described and illustrated in fig. 3.

Suction Temperature.

Direct measurements of the suction temperature were made at the City and Guilds (Engineering) College during the session 1912-13 on a Crossley gas-engine with a cylinder 7 inches in diameter, stroke 14 inches, and with a compression ratio of 4·8. The object of the experiment was to show how the suction temperature varied with the speed, with the jacket temperature, and with the mixture.

The apparatus with which the measurement was made has been already described (see pages 180, 181, 182, and 183). The results of the experiments are shown by the curves fig. 12. It is proposed to repeat these experiments on engines of more modern type and with higher compression ratios as soon as the development of the new laboratories at the College render it possible to do so.

The Cyclical Variation of the Temperature of the Charge in a Gas-engine Cylinder.

An example has already been given of the method of determining the cyclical variation of the temperature of the charge in a particular experiment, deducing it from the temperature measured at a point on the compression curve in combination with accurate indicator diagrams. The experiment was made at the City and Guilds (Engineering) College on the gas-engine already referred to. The engine is not of recent construction and therefore the compression ratio, viz. 4·8, is low compared with the ratios of gas-engines of more modern construction. Dr. Coker and Mr. Scoble have measured the cyclical variation of temperature on a more modern engine constructed by the National Gas-Engine Company in 1907. This engine has a cylinder 7 inches in diameter and a stroke of 15 inches. The maximum volume occupied by the charge is 5·8 times the minimum volume. The method adopted was to measure directly by means of a platinum couple the temperature at various points along the compression-curve and along part of the expansion-curve, but the highest temperature had still to be measured by using the charge itself as a gas-thermometer. A value of $\frac{PV}{T}$ is selected from a point on the expansion-stroke, and the constant so found is used to calculate the higher temperatures. In this method it is unnecessary to make any calculation regarding the chemical contraction before and after explosion because the temperature is measured after the explosion, but the rate of change of temperature at the point where the temperature is measured is very great, and therefore, in comparing the two methods, it is necessary to choose between a temperature measured when the rate of change is great with a corresponding lag and no correction for chemical contraction, as against a method of measuring the temperature when the rate of change is a minimum, viz. just after the closing of the suction-valve, and allowing

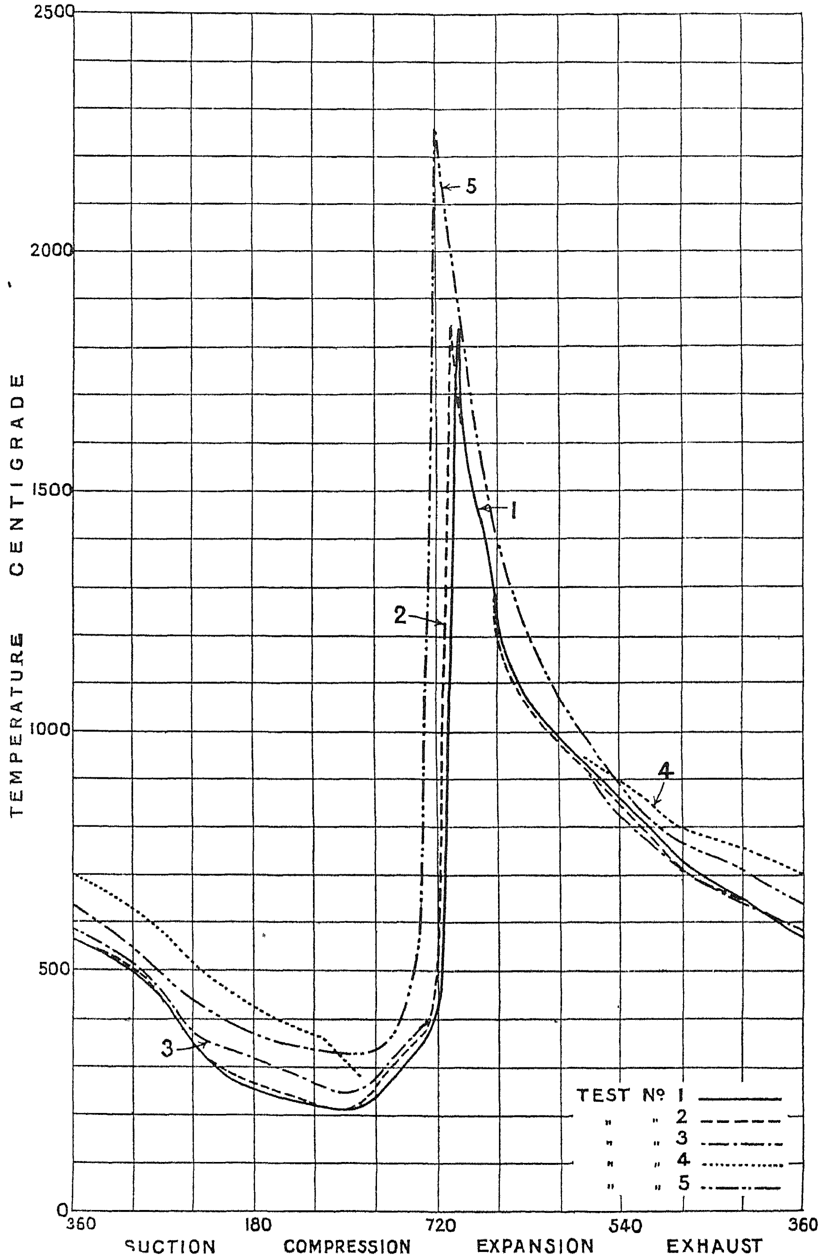

2500
2000
1500
1000
500
0
TEMPERATURE CENTIGRADE
360
180
720
540
360
SUCTION
COMPRESSION
EXPANSION
EXHAUST
1
2
3
4
5
TEST No 1
" " 2
" " 3
" " 4
" " 5

Fig. 13.

for chemical contraction. With suitable precautions both methods can be made to give consistent results.

The curve in fig. 13 shows the temperature cycle in a gas-engine cylinder determined by Dr. Coker and Mr. Scoble when the ratio of air to gas was 7·35 to 1. The jacket-temperature was 35·6° C., and the highest temperature calculated was 1836° C.

TEMPERATURE CYCLE OF GAS CHARGE.—CONDITIONS.

Curve Number	I.H.P.	Ratio of Air to Gas	Jacket Outlet Temp. °C.
1.	10·24	7·35/1	35·6
2.	9·96	7·08/1	37·2
3.	10·11	7·13/1	81·4
4.	10·36	6·71/1	40·6
5.	10·36	5·66/1	52·8
6.	9·74	6·64/1	43·7

Application of the Work of the Committee to Practical Problems.

The application of the work of the Committee to practical problems can be illustrated in connection with the calculation of the heat exchanged between the working agent and the walls of a gas-engine cylinder.

First Law of Thermodynamics and the quantities necessary to apply it to determine heat lost or gained by the working charge during a change of state.

Let A (fig. 14) be a point on the pressure volume diagram representing the state of a working agent with regard to its pressure and volume. Let the state change along the path A, B, so that B represents the state after the change. Then

$$\left\{\begin{array}{l}\text{The heat received by the}\\ \text{working agent from its}\\ \text{external environment}\\ \text{during the change of}\\ \text{state from A to B} = Q\end{array}\right\} = \left\{\begin{array}{c}\text{Mass of}\\ \text{charge}\end{array}\right\} \times \left\{\begin{array}{c}\text{The change}\\ \text{of its inter-}\\ \text{nal energy}\\ \text{per pound}\end{array}\right\} + \left\{\begin{array}{c}\text{The work}\\ \text{done by}\\ \text{the agent}\\ \text{on its en-}\\ \text{vironment}\end{array}\right\}. \quad (1)$$

That is, reckoning in thermal units,

$$Q = M\,(E_B - E_A) + \frac{Z}{J} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In which Q is measured in pound calories.
M is the mass of the charge in pounds.
E_B is the internal energy of the charge in its final state.
E_A is the internal energy of the charge in its initial state.
Z is the work done by the agent on its environment measured in foot-pounds.
J = 1,400.

Earlier it was assumed that the specific heat of the gas used in the gas-engine cylinder was constant, and that the change of internal energy was determined by the change of temperature only. With this assumption the first term on the right-hand side of the equation was

reckoned by merely multiplying the specific heat into the change of temperature corresponding to the change of state from A to B, the mass of the charge M being calculated from the general relation,

$$M = \frac{PV}{T} \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

corresponding values of P, V, and T being taken from any point on the path where they could be determined. It is known, however,

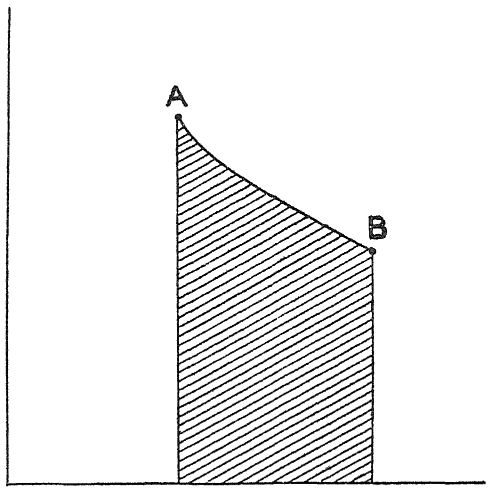


FIG. 14.

that the specific heat is variable, and the Committee began their work by reviewing all the available experimental data in connexion with the subject. Several members of the Committee were themselves carrying out researches in relation to this problem at the same time.

Data found to enable this Determination to be made.

The aim of the Committee was to ascertain the true value of the specific heat at constant volume, K_v, or, to put it in another way, to ascertain the relation between the internal energy of the gas and its temperature. In dealing with gas-engine problems it is more convenient to combine equations (1) and (2) into a single expression in which the specific heat is given not in terms of the unit of mass, but in terms of the unit of volume at standard pressure and temperature. Substituting in equation (3) for the standard pressure, 1 atmosphere, for the standard temperature, 273° C. absolute, and for the gas constant, $c = 96$, it will be found that the weight of a cubic foot of the working agent at standard temperature and pressure is ·081 lb., and therefore in terms of foot-pounds, and still assuming that the specific heat at constant volume is constant, equation (2) becomes,

$$JQ = \cdot 081 \, JK_v \text{ (change of temperature)} + Z.$$

The quantity 0·081 JK_v represents the change of internal energy in foot-pounds per degree change of temperature per cubic foot as measured at standard temperature and pressure. When K_v is variable and is a known function of T, say ϕ (T), the term becomes

$$0{\cdot}081\ J \int_{T_1}^{T_2} \phi(T)\, dT.$$

Values of this expression in which the lower limit T_1 is 0 degrees Centigrade can be read off the curve given in fig. 15, which is taken from the first Report.

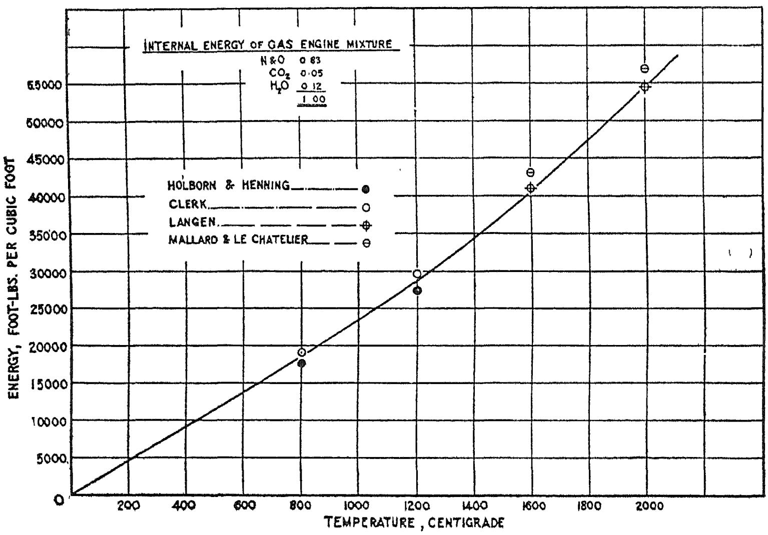


FIG. 15.

To use this curve to find the internal energy corresponding to a given state-point it is necessary to measure the pressure P and volume V from a PV diagram, and also to determine the absolute temperature T. The corresponding volume at standard temperature and pressure is then calculated from the equation,

$$V_0 = \frac{VP}{T}\frac{T_0}{P_0}$$

This calculated value of V_0 when multiplied by the internal energy as given by the curve for the temperature T gives the internal energy of the gas corresponding to the given state-point.

Symbolically let

E_A = internal energy corresponding to the position of a state-point A.

V_{A_0} = the corresponding volume measured at A reduced to standard temperature and pressure, and

Y_t = the ordinate of the curve measured at the temperature corresponding to the temperature of the state-point, then

$$E_A = V_{A_0}\ Y_t$$

The position of the points A and B on the PV diagram gives no indication of the temperature at A or B. If the temperature at one of the points, however, is known, then the temperature at the second point can be calculated from the relation

$$\frac{P_A V_A}{T_A} = \frac{P_B V_B}{T_B} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This relation expresses the characteristic equation for gases, and is quite independent of the specific heat of the gases concerned. It applies to all positions of the state-point in the PV diagram provided that the following two conditions are satisfied:—

Condition 1. That there is no change in density of the gas such as may be produced by some change in its chemical constitution.

„ 2. That the weight of the working agent during the change of state from A to B is constant.

It is fundamentally important, therefore, to be able to measure by direct observation the temperature corresponding to at least one position of the state-point in the diagram, because by means of this temperature and the relation expressed in equation (4) the temperature corresponding to any other position of the state-point in the diagram can be calculated, providing always that the conditions 1 and 2 are not violated during the change of state. If the first condition is violated there is a small change of volume caused by chemical action as the state-point moves from A to B, and in order to calculate the magnitude of this change it is necessary to have a chemical analysis of the gas before and after chemical action. When these analyses are known a correction can be made and equation (4) can still be applied to calculate the temperature. This kind of action has to be reckoned with, for example, if the state-point A is on the compression-curve of a gas-engine and the state-point B is on the expansion-curve.

The earlier part of this report shows that the Committee have given a good deal of consideration to the subject of the direct measurement of temperature, and that individual members have worked at the problem successfully. Examples have been given earlier in the report of methods which have been applied and are being used in the researches which are now being carried out. This example shows how the equation (4) is used to calculate the temperature for different positions of the state-point B from observations of a single temperature. The single temperature which it is most useful to know is the suction-temperature, and this may be defined as the temperature of the charge in the cylinder just after the admission valve is closed. There is then a definite weight of charge in the cylinder at a definite pressure and volume, and at a definite temperature. Allowing for the chemical contraction, equation (4) can be applied along the expansion-curve.

The Committee have examined into the question of leak of charge, and have come to the conclusion that in most cases in a modern engine it is a negligible amount when proper precautions are taken.

These considerations show how important the suction temperature is in combination with the indicator diagram, as from this temperature and the pressure and volume given by the diagram the state of the working agent all through the cycle can be determined, at least approximately.

The values of the suction temperature for a particular engine are exhibited in fig. 12 above, and a diagram of the kind would be useful in connexion with any internal-combustion motor.

To resume, it can now be assumed that it is possible to fix a temperature for one particular position of the state-point A, and then the temperature at the end of the change of state B, if not observed, can be calculated. With a knowledge of those temperatures the internal energy of the working agent can be read off from the curve (fig. 15), and then the first term on the right side of the equation, viz.

$$E_B - E_A = \text{change of internal energy}$$

is determined.

The value of the second term on the right side of equation (1) is merely the value of the shaded area under the path AB expressed in foot-pounds. Consequently, from a pressure-volume diagram giving the initial and final conditions of the working agent and the path of the state-point in between, together with the temperature corresponding to one position of the state-point, the right side of the equation can be determined and the heat gained or lost by the working agent during the change can therefore be computed. If there is no gain or loss of heat the work done is done at the expense of the internal energy of the working agent itself. One of the main objects of the Committee has been to extend our knowledge of the physical constants of the gases by the careful examination of methods, apparatus, and results of various investigators, including members of the Committee, and change of state of the working charge in a gas-engine can now be followed with a degree of accuracy which hitherto has been impossible.

A diagram from an actual gas-engine shows the PV changes during the whole of the four-stroke cycle, but the method explained above can only be applied to determine the heat exchanges during that part of the cycle when the weight of charge enclosed in the cylinder is constant—*i.e.* during the period between the closing of the suction-valve and the opening of the exhaust-valve. There is no difficulty in applying the method practically to a change of state along the compression-curve because the conditions 1 and 2 above are fulfilled. There is no chemical change and the weight of charge is constant. Applying the method to the analysis of the expansion-curve, however, there is difficulty. The left side of equation (1), Q, gives the heat gained or lost by the gas during a change of state. Q includes the heat gained by combustion as well as the heat gained or lost from outside, so that it must be written

$$Q = O + C$$

where O represents the heat gained or lost to the outside, and C repre-

sents the heat produced by combustion during the change. The difficulty is to separate these two during a change of state along the expansion-line. It is probable that combustion is not quite complete at the point of maximum pressure; in fact some combustion may be going on right up to the point at which the exhaust-valve opens. If, therefore, two points are taken on the expansion-curve and this method of analysis is applied, neglecting O, the heat loss determined will obviously be too great.

An analysis of the diagram by this method will be found in Dr. Clerk's Gustave Canet lecture, and need not, therefore, be further pursued.

Attention may be specially drawn to the curves in fig. 12, which show the results of trials made for the purpose of ascertaining the relationship between the suction temperature and the strength of the mixture used and on the speed. When the mixture is 9 parts of air and 1 part of gas by volume the suction-temperature is about 70° C. at a speed of 100 revs. per minute. At 200 revs. per minute the suction temperature is increased to 78½° C. At the constant speed of 200 revs. per minute the temperature gradually increases as the mixture becomes richer; with a 10 to 1 mixture the temperature is 75° C., and this increases to 96½° C. with a 6 to 1 mixture. At the lower speed the change in temperature is almost as great for a corresponding change in the mixture, namely from 67½° C. to 82° C. With a modern engine using a higher compression it is probable that the temperatures would be generally higher. Fig. 13 shows the cyclical variation of temperature as determined by Dr. Coker on a more modern engine, and the suction temperatures given by him are of the order of 200° C. Dr. Coker explains this high suction temperature as being partly due to the retention of hot gas and partly due to the long exhaust-pipe which was used.

Dalby and Callendar's experiments have shown that when using rich mixtures the maximum temperature in the cylinder is probably about 2000° C., and these results have been confirmed by Coker and Scoble. For the mixtures used in ordinary working conditions the experiments of Dalby, Callendar, Coker, and Scoble show that the temperature is about 1800° C. It is hoped to continue the experiments on temperature measurements when engines of more modern construction have been installed in the new engine laboratory of the City and Guilds (Engineering) College.

The concentration of research on the accurate measurement of temperature is a necessary step towards a more certain knowledge of the specific heat of gases at high temperatures; and the vital importance of this subject is indicated by the brief explanation given above of the method by which the determination of heat exchange between the working charge and the walls of the cylinder can be made. So far the Committee have only been able to present the curves given in fig. 15 as representing the most reliable data available. The practical use to which the curve can be put is illustrated by using the data given by it to find the efficiency of an engine working on the Otto cycle without loss of heat assuming that the mixture used is that

specified near the curve in fig. 15, this mixture being very much nearer the actual mixture used in a gas-engine than air.

Thermal Efficiency.

$\frac{1}{r}$	Efficiency calculated from the curve and for the mixture given in fig. 13	Efficiency of the air standard
$\frac{1}{2}$	·187	·242
$\frac{1}{3}$	·273	·356
$\frac{1}{4}$	·337	·426
$\frac{1}{5}$	·384	·475

The Committee are of opinion that they can usefully continue their work by organising research on the lines which have been foreshadowed in this report. The Committee recommend, therefore, that they be again re-appointed, and that, in view of the expensive nature of the research and the organisation involved, the sum of 100*l*. be granted to them.

Stress Distributions in Engineering Materials.—Report of the Committee, consisting of Professor J. PERRY (*Chairman*), Professors E. G. COKER *and* J. E. PETAVEL (*Secretaries*), Professor A. BARR, Dr. C. CHREE, Mr. GILBERT COOK, Professor W. E. DALBY, Sir J. A. EWING, Professor L. N. G. FILON, Messrs. A. R. FULTON *and* J. J. GUEST, Professors J. B. HENDERSON *and* A. E. H. LOVE, Mr. W. MASON, Sir ANDREW NOBLE, Messrs. F. ROGERS *and* W. A. SCOBLE, Dr. T. E. STANTON, *and* Mr. J. S. WILSON, *to report on Certain of the More Complex Stress Distributions in Engineering Materials.*

THE reports presented at the Birmingham Meeting of the Association led the Committee to the view that the co-ordination of the results of various researches was rendered difficult by the diversity of the materials used in the tests. It was therefore thought desirable to obtain complete and systematic data with regard to three definite materials, namely, a mild steel, a ·3 per cent. carbon steel, and a steel alloy.

In accordance with a resolution passed at the meeting of December 19, 1913, a stock of three tons standard steel has been obtained for the Committee by Dr. F. Rogers. This consists of :—(1) Dead mild steel (carbon ·12 per cent.); (2) Axle steel (carbon ·3 per cent.); (3) Nickel steel.

Some of the steel has already been sent to various members of the Committee, and in due course full information will be available with regard to the behaviour of the three materials under a large number of different tests.

The mild steel was kindly presented to the Committee by Messrs. Steel, Peech, and Tozer, and the axle steel by Messrs. Taylor Bros.

Information with regard to the manufacture of the standard steels is given in an Appendix.

A report on the 'Experimental Determination of the Distribution of Stress and Strain in Solids' has been presented by Professors Coker and Filon.

A paper on the 'Internal Stresses in a Built-up Steel Compression

Member,' by Mr. H. Delépine, has been communicated by Professor Petavel, and will be read at the meeting.

A number of members of the Committee have, during the past year, been engaged on subjects dealt with in last year's report, but in most cases the experimental work is not yet completed.

The subjects under investigation are the following :—

Professor Coker and Mr. Scoble : Shear Tests.

Mr. Cook : Tests of the Physical Constants of the Standard Steels.

Messrs. Cook and Robertson : Further Work on the Strength of Thick Cylinders.

Mr. Fulton : Alternating Stress at Low Frequencies.

Mr. Guest and Professors Dixon and Lea : Combined Stresses.

Mr. Mason : Repeated Combined Stresses.

Dr. Rogers : Alternating Stress, Heat Treatment, and Microscopical Examination.

Mr. Scoble : Repeated Combined Stresses.

Dr. Stanton : Repeated Shear Tests.

Mr. Mason has installed, in the Engineering Laboratory at the University of Liverpool, a machine specially designed for experimental work on alternating bending, alternating torsion, and simultaneous alternating bending and torsion. He has also constructed an apparatus for measurement of hysteresis.

Dr. Stanton has made arrangements to test the standard steels, firstly by reversals of simple shearing stress, then by superimposing bending and direct stresses.

Mr. Guest and Professors Dixon and Lea have completed the erection of their apparatus, and are engaged in preliminary experimental work.

The Committee ask to be re-appointed with a grant of 100*l*.

APPENDIX.

Outline of Manufacture of the Standard Steels.
By Dr. F. ROGERS.

No. 1 Steel. (·12 per cent. Carbon.)

The materials used in the manufacture of this steel are hematite pig iron, steel scrap and ore of the purest descriptions, melted very carefully in the acid open hearth furnace.

The composition is adjusted by the addition of ferro-manganese, after which the metal is cast into ingot-moulds. The ingots are then rolled, with several heatings, into bars, which are reeled when black-hot, giving a straightening and burnishing effect without injuring the steel.

This metal is suitable for high-class mild steel.

The bars supplied to the Committee are the whole usable portion of two ingots, and weigh nearly $22\frac{1}{2}$ cwts.

No. 2 steel (·3 per cent. carbon).

Report not yet received.

No. 3 steel ($3\frac{1}{2}$ per cent. nickel).

Report not yet received.

Experimental Determination of the Distribution of Stress and Strain in Solids. By Professors FILON *and* COKER.

Very little has been done hitherto in the way of determining directly the distribution of stresses and strains in the interior of an elastic solid. The

investigations which have been made deal almost exclusively with the more restricted case of two-dimensional stress and strain, or of stress and strain in a thin plate parallel to the faces of the plate itself, a problem known to elasticians as that of 'generalised plane stress.' [1]

In these cases two methods have proved available. The first method consists in measuring directly the deformations of the body studied, by observing the actual distortion of a face of the solid parallel to the plane of strain. In practice this may be done by ruling this face into squares and observing, with a kathetometer or micrometer, the relative shifts of various parts of the network. From these, the extent by which the angle at a node of the network has been changed from a right angle can easily be found, and this quantity, as is well known, measures the shearing strain (or 'slide,' according to a terminology followed by many writers on elasticity, who reserve the word 'shear' to denote the shearing-stress).

In this way values of the shearing-strain are obtained at the various nodes of the network. Again, the changes of distance between adjacent

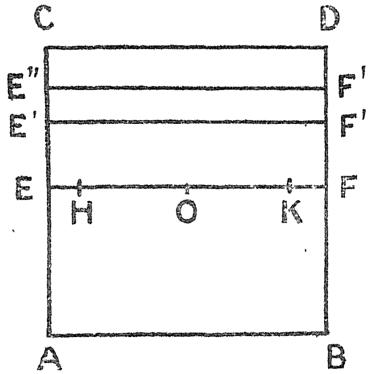


FIG. 1.

nodes can be found, and from these, if the squares of the network are sufficiently small, the extensions at the various nodes, parallel to the lines of the net, can be obtained.

The plane-strain can, therefore, be mapped out over the whole face of the solid which is under observation. If this method is to give satisfactory results it must be applied to materials where the strains are comparatively large. It has been applied with considerable success by Professor Karl Pearson (1) and various workers associated with him to models of dams constructed of gelatine-glycerine jelly, and in this way various results of interest in the theory of masonry dams have been obtained, although it cannot be said that the complete system of stresses in such dams is yet known with any certainty. In other cases measurements of the distortions produced in circles described on the face of a model have been used to determine the principal strains and their directions, as in the experiments of Messrs. Wilson and Gore (2).

Dr. E. N. da C. Andrade (3) has also employed a block of jelly to investigate the distribution of slide in such a block when two of its opposite

[1] Love, *Theory of Elasticity*, p. 135.

faces AB, CD (Fig. 1) constrained to remain plane and parallel and undisturbed are given a translatory displacement relative to each other, parallel to their plane.

Dr. Andrade found that along the middle plane EF of the block (halfway, that is, between the two faces whose displacement was prescribed) the distribution of slide gave two maxima at points H, K distant about one-sixth of the length from the unstressed faces perpendicular to the plane of strain, the slide falling gradually to a minimum at O.

For a section E′ F′ near the middle plane an effect of the same type occurred, but was less marked. For a section E″ F″ near the face CD where the constraint was applied the slide remained fairly uniform over the greater part of the length of the section, going down rapidly at the ends to the value zero at CD.

The problem attacked experimentally by Dr. Andrade is one of which no exact theoretical solution is known. Dr. Andrade himself attempted to fit his conditions by an approximate solution, but either through the failure of the approximation, or from some other cause, the results of observation and calculation agreed only qualitatively.

The second method used for the investigation of the distribution of stresses inside a plate subjected to stress in its own plane depends on the property, discovered by Sir David Brewster in 1816, and independently by Fresnel, that glass and other isotropic transparent substances become doubly refracting under stress.

Since then this effect has been studied by a number of observers (4). It may be taken as fairly well established that when a ray of polarised light traverses a plate stressed in its own plane, it is broken up into two components, polarised along the two lines of principal stress at the point where the ray crosses the plate, and the relative retardation of these two rays on emergence in air is

$$C\tau(P-Q),$$

where τ = thickness of the plate, P and Q are the two principal mean stresses in the plane of the plate, and C is a co-efficient depending upon the material and the wave-length of the light (5).

Clerk Maxwell (6) was the first to go fairly fully into the theory of the appearances presented when a plate under varying stress in its own plane is placed between crossed Nicols. He showed that the light is restored at all points except those for which :

(*a*) The lines of principal stress are parallel to the axes of the Nicols.

Since the condition for extinction of the light is here independent of the wave-length, these lines will be quite black. These may be called the lines of equal inclination or isoclinic lines.

(*b*) The principal stress-difference has such a value that $C\tau(P-Q)$ is an exact multiple of the wave-length.

These will be lines of equal principal stress-difference, and will give a different set of lines for different wave-lengths. They are thus, in general, brilliantly coloured, the same stress-difference corresponding to the same tint. The only exception is the line corresponding to $P-Q=0$.

These may be called (following Maxwell) the *isochromatic* lines, the black line corresponding to $P-Q=0$ being called the *neutral* line.

Observations of the isoclinic lines have the advantage that these lines are exhibited under comparatively small stress and are independent of the co-efficient C. Their use does not, therefore, require straining the

material to an extent likely to produce permanent set, and they can be shown by comparatively thin specimens. Also they do not require any previous investigation of the co-efficient C for the given material, or of its dependence upon the wave-length.

In theory observation of the isoclinic lines is sufficient to determine the stress system, provided we have information as to the actual stresses at a very limited number of points (7). Such information is generally available from the known boundary conditions.

On the other hand, the calculations required to actually deduce the stresses from the isoclinic lines are complicated, and are very difficult to apply to cases where the data are expressed by purely empirical curves.

The isoclinic lines are, therefore, better suited to experimental verification of stress distribution already known from theory, and for which the theoretical isoclinic lines can be calculated beforehand and compared with observation. They have been so used by M. Corbino and Trabacchi (8) using rings of gelatine to verify Volterra's (9) theory of internal strains in a multiply connected elastic solid; and also by Filon (10), who used glass beams to verify the ordinary theory of stresses in a beam at a distance from points of isolated loading, and also his own theory of the distribution of stress in a beam near a point of isolated loading. Both Corbino and Trabacchi, and Filon found that their experimental results confirmed the predictions of the theory of elasticity (11). Carus Wilson (12), who used in his investigation both the isoclinic and the isochromatic lines, was the first to apply the optical method to discover the laws of stress distribution in a glass beam, doubly supported and centrally loaded.

He gives a drawing of the lines of principal stress in such a beam, but does not use them further, and restricts his comparison of theory with experiment, to the stresses in the cross-section immediately under the load; the theory with which he compares his results was originally given by Boussinesq (13), and treats the height of the beam as infinitely thick. Sir G. G. Stokes gave, in a note to Carus Wilson's paper, an empirical correction to Boussinesq's theory. An exact theory of this problem has since been given by Filon (14).

The use of the isochromatic lines and generally of experiments depending upon tint has this advantage, that it yields directly the value of the stress-difference P—Q. If this be combined with a determination of the direction of principal stress at each point, then considerable direct information is given at once, and some cases of practical importance have been examined by Hönigsberg and Dimmer (15).

The determination both of P—Q and of the directions of principal stress may be combined in one measurement, which is very simply made by means of an apparatus due to Coker (16). Coker uses a thin celluloid plate, cut to represent an engineering structure in which it is desired to investigate the stresses. This is a more easily worked material than glass, and a lesser thickness is required, as its stress-optical co-efficient is considerable. To obtain a measure of the stress-difference at any point a tension member is placed in front of the strained model, in a direction corresponding to one of the principal axes of stress, and the colour effect produced in the loaded model is neutralised by applying a sufficient load to this calibrating member. The tensional stress T affords a measure of the difference of the principal stresses (P—Q) subject to a small correction when (P—Q) and T have different signs.

An improved way of doing this, which saves these repeated adjust-

ments of T, is to use a test-piece under pure flexure (without shear) in its own plane. This can be readily produced in a straining frame as in the accompanying diagram. The stress will then vary linearly from P to Q and may be read off along a scale PQ, which can be previously calibrated against a specimen under known tension.

A little sideways shift of the test-plate is then all that is required to compensate the stress-difference at any given point, provided that the direction of principal stress had been found previously.

Coker has used a calibration tension member to determine the distribution of stress in plates of various shapes—for example, in tension specimens

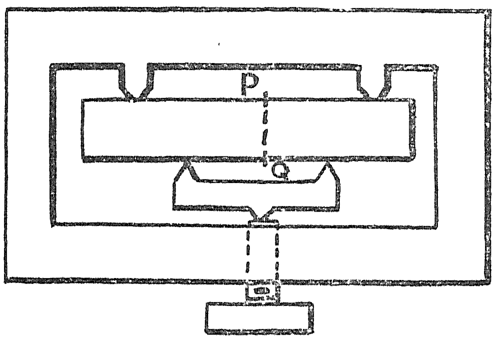


FIG. 2.

pierced with circular holes, decks of ships with various openings, cement briquettes, &c. (17). He has also (18) investigated Andrade's problem of the block whose opposite faces slide with regard to one another remaining undistorted, and he obtains by this optical method a distribution of shear very similar to that obtained by Andrade from direct measurements of the slide. Mr. Scoble and he have also applied this method to determine the distribution of stress due to a rivet in a plate (19).

The photo-elastic determination of stress carried out in this way does not, however, determine the stress in the plate completely. It will be noticed that all the method gives is the principal *stress-difference* at any point. If each principal stress at a given point be increased by any arbitrary quantity, the appearances are in no wise altered. To obviate this, Coker has used the stretch-squeeze effect in the plate to measure the sum P—Q of the principal stresses, a suggestion due originally to Mesnager (20). For clearly, if τ be the thickness of the plate, η Poisson's ratio, the plate, at the point where the principal stresses are P, Q, will become thinner by an amount $\eta\tau(P+Q)$ an amount which is small, but with delicate instruments not impossible to measure.

It will be noticed that this provides yet a third method for exploring the field of stress in a plate.

There is, however, no necessity for doing this, as the information derived from the known values of the stress-difference and the direction of the lines of principal stress can be readily applied to find the complete system of stresses.

Let the axes of x and y be taken in the plane of the plate. Let P and Q now denote the normal stresses across elements dy and dx respectively, S the shearing stress across either of the above elements. Then, if the

lines of principal stress make an angle α with the axes, and if R is the principal stress-difference, it is well known that

$$P-Q=R\cos 2\alpha$$
$$2S=R\sin 2\alpha.$$

Thus a determination of R and α at every point leads to the value of S at all points.

On the other hand, considering the equilibrium of a small rectangle dx, dy and neglecting body-forces, we have the well-known body stress equations for generalised plane strain,

$$\frac{\delta P}{\delta x}+\frac{\delta S}{\delta y}=0, \qquad \frac{\delta S}{\delta x}+\frac{\delta Q}{\delta y}=0.$$

Now, at a point of the boundary, all the stresses will be known.

For the normal stress across an element of the boundary where the outwards normal makes an angle with the axis of x is

$$P\cos^2\theta+Q\sin^2\theta+2S\cos\theta\sin\theta$$
$$=\frac{P+Q}{2}+\frac{P-Q}{2}\cos 2\theta+S\sin 2\theta.$$

S and P—Q being known from optical data, and the normal stress across the boundary being also known from the boundary conditions, the above equation determines P+Q and hence (P—Q being known) P and Q.

Consider now a point A of the plate. Draw a line through A parallel to the axis of x to meet the nearest boundary at a point A_0 (x_0, y).

Then, integrating the equation

$$\frac{\delta P}{\delta x}+\frac{\delta S}{\delta y}=0$$

along the line A_0 A, we find

$$P-P_0=-\int_{x_0}^{x}\frac{\delta S}{\delta y}\cdot dx,$$

where P_0 is the value of P at A_0.

Similarly, if a line through A parallel to the axis of y meets the nearest boundary at a point B_0 (x, y_0) when the value of Q is Q_0,

$$Q-Q_0=-\int_{y_0}^{y}\frac{\delta S}{\delta x}\cdot dy.$$

Now, if we know the value of S at all points, the values of the partial differential co-efficients $\frac{\delta S}{\delta x}$, $\frac{\delta S}{\delta y}$ can be obtained approximately by taking differences. P and Q can then be found as above by the ordinary process of graphical integration, P_0, Q_0 being known, as explained. This method can be used with any set of experimental data, provided only that these are accurate enough to allow of differences being taken to calculate $\frac{\delta S}{\delta x}$, $\frac{\delta S}{\delta y}$. In any case, before actually applying the method, the curves for S when either x = constant or y = constant should be 'smoothed' so

as to take out accidental inequalities. A check on the accuracy of the calculation is easily provided, for the calculated $P-Q$ should agree with the value optically observed.

In many problems it is known that one of the normal stresses is throughout very small. In this case, if Q, say, is nearly zero, we have $P=R\cos 2\alpha$, and the stress difference leads easily to the complete system of stresses. This assumption has been made by Coker in his earlier papers, but it would seem desirable to justify it more fully.

NOTES.

(References to these are given in the text.)

(1) Karl Pearson, A. F. C. Pollard, C. W. Wheen, and L. F. Richardson: An Experimental Study of the Stresses in Masonry Dams. (Drapers' Company Research Memoirs: Technical Series V.)

(2) J. S. Wilson and W. Gore: Stresses in Dams. 'Proc. Inst. C.E.,' 1908.

(3) E. N. da C. Andrade: The Distribution of Slide in a Right Six-face Subject to Pure Shear. 'R.S. Proc. A.,' vol. 85, pp. 448–461.

(4) Sir David Brewster: 'Phil. Trans.' 1816, p. 156. 'Annales de Chimie et de Physique,' vol. xx. Fresnel: 'Œuvres d'Augustin Fresnel,' tome 1, p. 713. F. E. Neumann, 'Abh. d. k. Acad. d. Wiss. zu Berlin,' 1841, vol. ii., p. 50–61. See also 'Pogg. Ann.' vol. liv. John Kerr: 'Phil. Mag.,' 1888, ser. 5, vol. 26, No. 161. G. Wertheim: 'Annales de Chimie et de Physique,' ser. 3, vol. xl., p. 156.

(5) F. Pockels: 'Ueber die Aenderung des optischen Verhaltens Verschiedener Gläser durch elastische Deformation,' Ann. d. Physik, 1902, ser. 4, vol. 7, p. 745. L. N. G. Filon: On the Variation with the Wave-length of the Double Refraction in Strained Glass, 'Camb. Phil. Soc. Proc.,' vol. xi. Pt. vi., vol. xii. Pt. i., and vol. xii. Pt. v. On the Dispersion in Artificial Double Refraction, 'Phil. Trans. A.,' vol. 207, pp. 263–306 (1907). Preliminary Note on a New Method of Measuring directly the Double Refraction in Strained Glass, 'R.S. Proc. A.,' vol. 79, pp. 440–442 (1907). Measurements of the Absolute Indices of Refraction in Strained Glass, 'R.S. Proc. A.,' vol. 83, pp. 572–578 (1910). On the Temperature Variation of the Photo-elastic Effect in Strained Glass, 'R.S. Proc. A.,' vol. 89, pp. 587–593 (1914).

(6) Clerk Maxwell: 'Trans. Roy. Soc. Edin.,' vol. xx., 1853, p. 1172; or 'Collected Papers,' vol. i.

(7) A proof of the statement in the text is as follows:—Let E be the stress function for generalised plane stress (Love: 'Theory of Elasticity,' pp. 86 and 446), P, Q, S the mean stresses $\widehat{xx}$, $\widehat{yy}$, $\widehat{xy}$ in the usual notation, R the principal mean stress-difference, ϕ the angle which the lines of principal stress make with the axes.

Then it is known that

$$R^2=(P-Q)^2+4S^2$$
$$\tan 2\phi=2S/P-Q$$
$$2S=P\sin 2\phi \qquad P-Q=R\cos 2\phi.$$

Also the mean stresses are given in terms of the stress function by

$$P=\frac{\delta^2 E}{\delta y^2}, \qquad Q=\frac{\delta^2 E}{\delta x^2}, \qquad S=-\frac{\delta^2 E}{\delta x,\ \delta y}.$$

Using the transformations

$$2\xi = x + \iota y$$
$$2\eta = x - \iota y$$

we find readily

$$Q + \iota S = \frac{\delta}{\delta x}\left(\frac{\delta E}{\delta \xi}\right) \qquad Q - \iota S = \frac{\delta}{\delta x}\left(\frac{\delta E}{\delta \eta}\right)$$

$$S + \iota P = -\frac{\delta}{\delta y}\left(\frac{\delta E}{\delta \xi}\right) \qquad S - \iota P = -\frac{\delta}{\delta y}\left(\frac{\delta E}{\delta \eta}\right)$$

$$\therefore\quad Q - P + 2\iota S = \frac{\delta^2 E}{\delta \xi^2} \quad (1) \qquad Q - P - 2\iota S = \frac{\delta^2 E}{\delta \eta^2} \quad (2)$$

$$Q + P = \frac{\delta^2 E}{\delta \xi \,.\, \delta \eta} \quad (3)$$

From (1) and (2)

$$-R\epsilon^{-2\iota\phi} = \frac{\delta^2 E}{\delta \xi^2} \qquad -R\epsilon^{2\iota\phi} = \frac{\delta^2 E}{\delta \eta^2}$$

$$\therefore\quad \epsilon^{4\iota\phi}\frac{\delta^2 E}{\delta \xi^2} = \frac{\delta^2 E}{\delta \eta^2} \quad (4)$$

Now, the isoclinic lines give ϕ as a function of x, y and therefore of ξ, η for every point.

On the other hand, it is well known that E satisfies the equation

$$\underset{x,y}{\nabla^4} \,.\, E = 0$$

or

$$\frac{\delta^4 E}{\delta \xi^2 \,.\, \delta \eta^2} = 0,$$

of which the solution is

$$E = E_1(\xi) + E_2(\eta) + \eta E_3(\xi) + \xi E_4(\eta) \quad (5)$$

E_1, E_2, E_3, and E_4 being arbitrary functions.

(4) then gives

$$\epsilon^{4\iota\phi(\xi,\eta)}\Big[E_1''(\xi) + \eta E_3''(\xi)\Big] = E_2''(\eta) + \xi E_4''(\eta) \quad (6)$$

Putting $\eta = 0$, $\xi = 0$ successively in the identity (6)

$$E_1''(\xi) = \epsilon^{-4\iota\phi(\xi,0)} \,.\, \Big[E_2''(0) + \xi E_4''(0)\Big] \quad (7)$$

$$E_2''(\eta) = \epsilon^{4\iota\phi(0,\eta)} \,.\, \Big[E_1''(0) + \eta E_3''(0)\Big] \quad (8)$$

Differentiating (6) with regard to ξ,η and then putting $\xi=0$ and $\eta=0$ respectively, we find

$$E_4''(\eta)=\left\{\frac{\delta}{\delta\xi}\cdot\epsilon^{4\iota\phi}\left[E_1''(\xi)+\eta E_3''(\xi)\right]\right\}_{\xi=0}$$

$$E_3''(\xi)=\left\{\frac{\delta}{\delta\eta}\epsilon^{-4\iota\phi}\left[E_2''(\eta)+\xi E_4''(\eta)\right]\right\}_{\eta=0}$$

i.e.,

$$E_4''(\eta)=4\iota\left(\frac{\delta\phi}{\delta\xi}\right)_{0,\eta}E_2''(\eta)+\epsilon^{4\iota\phi(0,\eta)}\left\{E_1'''(0)+\eta E_3'''(0)\right\} \quad (9)$$

$$E_3''(\xi)=-4\iota\left(\frac{\delta\phi}{\delta\eta}\right)_{\xi,0}E_1''(\xi)+\epsilon^{-4\iota\phi(\xi,0)}\left\{E_2'''(0)+\xi E_4'''(0)\right\} \quad (10)$$

Assume $E_1''(0)=A$, $E_3''(0)=B$, $E_1'''(0)=C$, $E_3'''(0)=D$.

Equations (7)–(10) determine $E_2''(\eta)$, $E_4''(\eta)$ and hence $E_1''(\xi)$, $E_3''(\xi)$ as homogeneous linear functions of A, B, C, D.

Hence $E=Ae_1+Be_2+Ce_3+De_4+\alpha\xi+\beta\eta+\gamma\xi\eta+\delta$, where e_1, e_2, e_3, e_4 are now known functions and α, β, γ, δ are arbitrary constants.

The terms in α β δ do not affect the stresses and may be dropped.

The term γ ξ η may add γ to P+Q.

If, now, the value of any stress be known at a given point, this leads to a linear equation between A, B, C, D, γ.

Hence the complete specification of the stress at two points leads to six equations for A, B, C, D, γ in like manner, if we consider the conditions at the boundary, where two of the stresses are in general known, the conditions at three points give six equations. In either case we have more than enough equations to determine A, B, C, D, γ.

Thus the stress conditions at a few points, together with the isoclinic lines, determine the stress system completely.

(8) O. M. Corbino and Trabacchi: 'Rendiconti Acad. dei Lincei,' vol. 18, 1909. See also letter by O. M. Corbino in 'Nature,' Jan. 16, 1913.

(9) Volterra: 'Annales de l'Ecole Normale de Paris,' 1907.

(10) L. N. G. Filon: The Investigation of Stresses in a Rectangular Bar by Means of Polarised Light, 'Phil. Mag.,' Jan. 1912.

(11) Volterra, *loc. cit.* Note (8); Corbino, *loc. cit.* Note (7). Filon, *loc. cit.* Note (9); also Filon, 'Phil. Trans. A.,' vol. 201, pp. 63–155.

(12) Carus Wilson: 'Phil. Mag.,' ser. 5, Dec. 1891.

(13) Boussinesq: 'Comptes Rendus,' vol. 114, pp. 1510–1516. See also Flamant: 'Comptes Rendus,' vol. 114, pp. 1465–1468.

(14) L. N. G. Filon: On an Approximate Solution for the Bending of a Beam of Rectangular Cross-section under any System of Load: 'Phil. Trans. A.,' vol. 201, pp. 63–155.

(15) O. Hönigsberg and G. Dimmer: Interferenzfarben beanspruchter durchsichtiger Körper. O. Hönigsberg: Unmittelbare Abbildung der neutralen Schichte bei Biegung durchsichtiger Körper in zirkularpolarisierten Licht, 'International Association for Testing Materials,' Brussels Congress, 1906.

(16) E. G. Coker: The Determination by Photo-elastic Methods, of the Distribution of Stress in Plates of Variable Section, with some Applications to Ships' Plating, 'Transactions of the Institution of Naval Architects.' See especially pp. 9–11.

(17) E. G. Coker: Paper cited in Note 14 and the following:—The Optical Determination of Stress, 'Phil. Mag.,' 1910. The Distribution of Stress at the Minimum Section of a Cement Briquette, 'International Association for Testing Material,' 1912. The Effects of Holes and Semi-circular Notches on the Distribution of Stress in Tension Members, 'Physical Society of London,' 1913.

(18) E. G. Coker: An Optical Determination of the Variation of Stress in a Thin Rectangular Plate subjected to Shear, 'Proc. Roy. Soc.,' 1912.

(19) E. G. Coker and W. A. Scoble: The Distribution of Stress due to a Rivet in a Plate, 'Transactions of the Institution of Naval Architects,' 1913.

(20) A. Mesnager: Mesure des efforts intérieurs dans les solides et applications, 'International Association for Testing Materials,' Buda-Pesth Congress, 1901.

The Lake Villages in the Neighbourhood of Glastonbury.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), Mr. WILLOUGHBY GARDNER (*Secretary*), Professor W. RIDGEWAY, Sir ARTHUR J. EVANS, Sir C. HERCULES READ, Mr. H. BALFOUR, *and* Mr. A. BULLEID, *appointed to investigate the Lake Villages in the Neighbourhood of Glastonbury in connection with a Committee of the Somersetshire Archæological and Natural History Society. (Drawn up by* Mr. ARTHUR BULLEID *and* Mr. H. ST. GEORGE GRAY, *the Directors of the Excavations.)*

THE fifth season's exploration of the Meare Lake Village by the Somersetshire Archæological and Natural History Society began on May 13, 1914, and will be continued until May 27 (exclusive of filling in). The ground being excavated is situated in the same field and is continuous with the work of previous years. As the report has to be sent in on May 22, while the excavations are in progress, any notes regarding the work will necessarily be incomplete and curtailed. There has been considerable difficulty this year in procuring labour, and it is proposed to reopen the excavations in September. The digging includes the examination of the ground situated to the north-east of Dwelling-Mound V., south-east of Dwelling-Mound VII., the south-west quarter of Dwelling-Mound IX., and the ground lying to the north-east of Dwelling-Mound XVIII. There is little of interest, so far, to note structurally, but the number and importance of the objects found have been well maintained.

THE RELICS.

This report is called for before the season's work is half completed, and at a time when the excavators are only on the fringe of two well-defined dwelling-mounds. Hence there is little to say with regard to the relics so far discovered.

Bone.—The bone objects include part of two needles, worked tibiæ of sheep and ox, tarsal and carpal bones of sheep, cut and perforated

shoulder-blades, polishing-bones; and a long tubular die with numbers, 3, 4, 5, 6, represented by small circular depressions on the sides, and of a similar variety to those found in the Glastonbury Lake Village; also a piece of bone cut for the formation of two dice. A bone object of a new type is the coarse comb of rude workmanship formed from a rib-bone of ox or horse; there are eight large, clumsy teeth of varied size, which bear evidence of considerable wear; it is quite of a different character from the weaving-combs so frequently found in the lake villages.

Crucibles.—Several fragments.

Bronze.—The bronze objects include a piece of bordering, two fibulæ of safety-pin design (La Tène III.), one in almost perfect condition, and a small ornamented ring-handle, perhaps of a vessel. A long tubular object formed from a strip of sheet bronze was also found, the working-end of which is trifurcated by splitting the metal for a distance of about ¾ inch, each of the divisions tapering to form a three-pointed instrument.

Iron.—Parts of knives and fragments of pointed objects.

Flint.—A few flint flakes, some with secondary chipping.

Glass.—A perfect bead of clear white glass, ornamented with three sunk spiral devices filled with a light yellow paste, has been added to the bead series; and others have been found in addition.

Antler.—Part of a polished tine, a small tubular object, a cut piece with partial perforations, two weaving-combs, 'cheek-pieces,' and tool-handles.

Kimmeridge Shale.—Part of a fluted armlet of large size, lathe-turned; and portions of three others.

Tusks.—Several boars' tusks (? wild), including one perforated.

Querns.—No complete upper or lower stone has been found, but several large portions of well-worked saddle and rotary querns have been uncovered in Mound IX.

Other Stone Objects.—Several sling-stones, found singly; a large number of whetstones; a few small smooth pebbles (perhaps *calculi*).

Spindle-whorls.—Six have been found so far, (*a*) one of baked clay, (*b*) four of lias stone, (*c*) a part of one formed from an ammonite.

Baked Clay.—Several sling-bullets of fusiform shape have been collected; also a large triangular loom-weight and fragments of others in Mound IX.

Pottery.—No complete vessel has been found, but shards are very abundant in proportion to the area dug. The rougher wares are strongly represented, but a fair number of ornamented pieces have been collected, including some new and elegant designs. Part of an ornamented pot-cover of a type previously found at Meare has been found; also at least two separate fragments of Roman ware of the 'Burtle type,' obtained from below the alluvial deposits and on the original surface of Roman times.

Animal Remains.—Large quantities of bones of domesticated animals are being collected, chiefly of young animals. Many split bones and splinters have been noticed. Bird-bones are also commonly found. A cock-spur has also come to light at Meare, which implies that

the sport of cock-fighting, common in Gaul before the Roman conquest, was carried on in the lake village of Meare, as well as in that of Glastonbury.

The Committee are desirous that they should be authorised to act for the ensuing year on the part of the British Association, and that a grant of 20*l.* should be made in aid of the exploration that is mostly paid for by local effort.

Physical Characters of the Ancient Egyptians.—Report of the Committee, consisting of Professor G. ELLIOT SMITH *(Chairman)*, Dr. F. C. SHRUBSALL *(Secretary)*, Professor A. KEITH, Dr. F. WOOD JONES, *and* Dr. C. G. SELIGMANN.

Professor Elliot Smith's Report.

THIS report deals with two distinct series of anthropological material, (A) one from Saqqara in Lower Egypt, and (B) the other from the Southern part of the Kerma basin in the Sudan. Both collections are of quite exceptional importance from their bearing upon the history and the racial movements in the Nile Valley.

(A.) The Committee was appointed primarily with the object of acquiring, studying, and, if feasible, transporting to England a valuable and unique series of skeletons of Ancient Egyptians, buried in mastabas of the Second and Third Dynasties at Saqqara, which Sir Gaston Maspero, Director-General of the Egyptian Government Antiquities Department, had placed at my disposal. The material was brought to light in the course of the excavations carried on for the Antiquities Department by its Senior Inspector, Mr. J. E. Quibell, who did everything in his power to facilitate and help me in my investigations. The cemetery in which the material was obtained is situated a short distance to the north of the Pyramids of Saqqara, and included the tomb of Hesy, from which the famous wooden portrait panels (now in the Cairo Museum) were obtained by Mariette Pasha many years ago. The tombs themselves are of very great interest, and will be described in detail in Mr. Quibell's official report,[1] a summary of which was read at the Dundee Meeting. They are the earliest known examples of elaborate subterranean rock-cut tombs, and range in date from the latter part of the Second Dynasty until well into the period of the Third Dynasty. At the Dundee Meeting of the Association I read Mr. Quibell's account of this cemetery, from which the following extracts[2] have been taken:—

'This is the area in which Mariette found most of his mastabas, from which much of the knowledge of the Old Kingdom has been obtained.'

[1] Excavations at Saqqara, 1910-1911, Service des Antiquités de l'Egypte.

[2] These extensive quotations, not published hitherto, are necessary to explain the importance and precise significance of the anthropological questions involved in the study of the material, to the consideration of which I shall return in the latter part of this report.

'More than 400 tombs were dug and recorded: they were singularly uniform in type and cover but a small period in time. Four were of the First Dynasty, and the rest of the Second and Third. Intrusive burials of later ages were confined to two periods, that of Thotmes III. and (probably) late Ptolemaic, and were unimportant.'

'In what follows we will confine ourselves to the Second and Third Dynasties:—

'These tombs were most varied in size, but uniform in plan. One was 50 mètres long and 30 wide, but the one I have chosen as a type was no more than 1½ mètres long, and even originally not 1 mètre high. It consists of a hollow oblong of unbaked brickwork filled in with gravel and stone chip, plastered and whitewashed externally. On the east side are two niches, the southern one being the larger and the more important. Below the mastaba was a small stairway and a subterranean chamber. The smaller tombs were often built in rows, and their position parallel with the sides of the larger ones suggested that they belonged to the servants or relatives of the great men.

'One tomb showed very clearly the origin of the later type in stone. The niche has been withdrawn into the body of the building and protected by a door. A small chamber is thus formed, and the sides of this were, no doubt, decorated with paintings; later, when stone replaced the crude brick, the scenes were made in low relief. This is the form of most of the mastabas published by Mariette; the more complex plans of the large tombs that have been left open are exceptional.

'The paths between the tombs were very narrow, hardly wide enough for one man to pass, and among the larger tombs, where there were walls 3 mètres and more high, must have formed a perilous maze. They were much used; offerings of minute quantities of food were brought on every feast day and placed before the false doors in little vases like egg-cups and saucers. Piles of these pots are found thrown away near some of the tombs.

'Very little stone-work was found. Small tanks 20 centimètres or so long occasionally remained before the niches, and in two cases an inscribed stone panel depicting the deceased seated before his table of offerings had escaped the search for lime. This panel appears in the middle of the later stelæ of the Fifth Dynasty, of which it was evidently the most important part.

'The sides of the niches may have borne painted decoration—probably did so—but no trace of this remained.

'In one mastaba, a very large one, the wall was double: the two niches were carefully built in both the inner and the outer walls, evidently in order that the inner one might retain its magical value, even if the outer one were destroyed.

'The space inside the four walls was generally filled with gravel and with stone chip from the subterranean chamber, but in some of the larger tombs the filling contained also a great number of coarse vases, many crushed by the overlying gravel, but many also unbroken. These we thought at first might have been the jars used by the workmen for food, but some of them were of unbaked clay, and could hardly

have been used at all. In other cases, too, these vases had been placed in orderly rows; in one the whole desert floor between the walls of the tomb and the edge of the shaft had been covered with these vases, with clods of black clay placed between them. It would seem, then, that these were deposits intended to supplement the furniture of the subterranean chamber.

'In the case here shown there can be little doubt. Below the filling, hidden beneath 3 mètres of gravel, we found a shallow trench ½ mètre wide, once roofed with wood. Inside it were two rows of jars or model barns, each 30 centimètres high, made of unbaked clay, and containing a brown organic powder, probably decayed corn. The trench is lined with brick, and from it a tiny tunnel, a handbreadth wide and high, leads to the mouth of the shaft. This, surely, was a secret supply of food for the dead man.

'In three of the large tombs a still more elaborate provision was made. A row of brick chambers, or tanks, was sunk in the floor of the tomb, filled with jars, and covered with a course of brick. What the jars contained is not clear; a very light organic matter, probably a fat, filled the lower half of a few, but most of them were empty when found. These chambers, or tanks, must, however, have once contained something of value, for in one tomb they had been laboriously robbed. A shaft had been sunk through the filling—in this case composed of a very tough, dried mud—into one of the chambers, and from this tunnels had been forced, sometimes through the walls, sometimes above them through the mud filling, till all the eight chambers had been rifled. The labour must have been considerable and the risk not trifling: there was nothing to show how it had been repaid.

'We now leave the structures above ground and come to the shaft.

'This was nearly always in the form of a stair, sloping down from the north or east to the chamber mouth. The stair often starts from the east, near the north niche, and bends at a right-angle half-way down; this would be practically useful while the digging was going on, as it would stop a falling stone before it acquired an awkward velocity. The shafts, like the tombs, vary much in size. Some are 12 mètres deep, some so small—1 mètre or less—that the steps would be of no practical use.

'In the larger and deeper tombs the steps are cut in the rock, are of reasonable size, and evidently served their purpose in the excavation of the chamber below; but in many of the moderate sized mastabas, those 4 to 5 mètres long, the steps are of brick, and are too narrow and fragile for a man to stand on them. Shafts and steps in the small tombs, and presumably also in the large ones, were carefully plastered and whitewashed for the funeral ceremony. In small tombs a low skirting wall a few inches in height was built round the shaft, and this, too, was whitened. The upper part, the mastaba, was built after the funeral. But in larger tombs this was not practical; the works above and below ground had to go on together, so the stair was fenced in by a separate wall.

'Shafts were generally filled with gravel, the portcullis being relied on to secure the mouth of the chamber; but in large tombs they were

filled with slabs of stone, packed in on edge, and in some cases a pavement of heavy blocks was laid in above. A few stone vases were occasionally placed in the shaft, and in one tomb a great number had been laid on the steps of the stair. The same arrangement was found by Garstang in a great tomb at Bêt Khallaf.

'The portcullis consisted of a large flat block of stone with rounded edges, sometimes as much as 3 mètres long and 1·5 mètres wide, which fitted into a groove cut in the rock. It must have been lowered before the mastaba was built and chocked up so that its base was above the door of the chamber. Ropes were used to aid in lowering it; the channels cut by them were observed in one stone.

'The chamber opened either on the south or west, very rarely the north, never on the east.

'It was generally a small, rudely-cut cave, too small to hold a body laid at full length; this small rough chamber was the general rule, but the larger tombs have a series of chambers of a somewhat elaborate plan.

'On passing the portcullis in these we find ourselves in a broad passage, from which three or four chambers, probably magazines, open on each side.

'A wide doorway at the end leads to a continuation of the passage, and this to further chambers, in which there is some variety of plan; but two features are constant. To the right—that is, to the S.W.—is the actual burial chamber with remains of a single skeleton; in the S.-E. corner is a feature new in Egyptian tombs, and, surely, in any other tombs—viz., a dummy latrine; north of this, in two cases, was a narrow chamber with rude basins carved in the floor—probably meant for a bathroom. The provision for the dead was evidently more thoughtful and complete than in later ages.

'In all these underground chambers the antiquities found were somewhat disappointing. It is true that we did obtain a great number of bowls and dishes of alabaster, diorite, and other stones—indeed, an embarrassing quantity of them—also ewers and basins of copper, occasionally a wooden piece from a draughtsboard, a box or a bit of ivory inlay, and that the mud-seals on the vases were in three tombs inscribed with Kings' names, thereby giving us our assured dates for the cemetery; but the ancient robbers had very different returns for their labour; there had certainly been quite other classes of monuments of which no sample had survived. All the tombs except the very smallest and poorest had been robbed, and robbed, too, at a very early period: this was clear from the knowledge shown by the robbers of the construction, and the skill with which they penetrated to the burial chamber with a minimum of labour. Sometimes the earth inside the chamber had been passed through a sieve: this shows that the second robber had found some gold beads left behind by the first; he (the first one) would not need a sieve—he found the coffin and all the furniture lying clear.

'We assume that there was a coffin in all cases—indeed, fragments were often found, but complete coffins remained in four tombs only, and these four of the poorest.

'They are short, with panelled sides and arched square-ended lid:

two niches are made in the east side. In one coffin, the east side of which alone is here shown, the central panels are covered with a series of slabs; these are rounded at the ends and do not, as one would expect, butt against or mortise into the uprights; this suggests that they are in imitation of a door.' [Similar coffins were subsequently found by Professor Flinders Petrie in a contemporary cemetery on the opposite bank of the river.]

'When the east side of the coffin is taken away the body appears, sharply contrasted, with head to the north and face east. The limbs are swathed in linen bands, and masses of linen folded together lie above the body. There was some little evidence of an attempt at mummification, but no flesh remained on the bones; those of the arm lay free inside a wide cylinder of wrappings, which retained the shape of the limb. The preservation of these coffins and bodies was partial; some of the wood was quite sound, other pieces could not be moved. So of the cloth; some had been eaten by white ants, but some was in admirable preservation.

'About fifty skeletons and parts of skeletons were found in fair condition, and these, happily, owing to the visit of Professor Elliot Smith, could be carefully examined, some of them before they had been touched.

'In one only of all these four hundred tombs have paintings been found, but this is of very considerable interest, and the paintings are so extensive that our time for a whole season has been mainly occupied in copying them. This is the tomb of Hesy.

'The panels of Hesy have been, for more than forty years, in the Museum; they were brought there by Mariette, who discovered them and attributed them, correctly, to the Third Dynasty.'

These quotations from Mr. Quibell's report will make it clear that we are dealing with the remains of the very people who were responsible for technical inventions of far-reaching importance in the history, not merely of Egyptian craftsmanship, but of that of the whole world. This series of tombs reveals the stages in the acquisition of the means of cutting out extensive rock tombs; and it is a matter of considerable significance to determine the precise racial characteristics of the people who invented and were the first to practise these arts and crafts which were destined to exert so profound an influence on the world's culture.

The crucial importance of the human remains buried in these tombs depends upon the fact that the earliest bodies hitherto found in Lower Egypt (exclusive of those brought to light at Turah in the winter of 1909-1910 by Professor Hermann Junker, and described by Dr. Derry, to which reference will be made later) belonged to a later period—Fourth to Sixth Dynasties—and revealed undoubted evidence of considerable alien admixture, such as does not occur, except in rare sporadic instances, in the earlier remains from Upper Egypt. The problem for solution was the determination of when and how this process of racial admixture began.

The contemporary and earlier material found by Professor Junker upon the opposite (east) bank of the river, and a little further north,

was in a very bad state of preservation, and no adequate photographic record was obtained to permit of exact comparisons with other collections. But Dr. Derry's report, which seems to suggest that the alien element in these poorer graves did not become certainly appreciable until the time of the Third Dynasty, served to add to the interest of Mr. Quibell's material, and to make it more than ever desirable to secure and preserve a collection of such crucial importance for the investigation of the problems of Egypt's anthropological history.

The chief difficulty that faced me was how satisfactorily to deal with a collection of most fragile bones, a large proportion of which were certain to become damaged, more or less severely, during transport. As there was no anthropologist on the spot to measure and make descriptive notes on the material, it was proposed to employ experts to photograph each skull, and other important bones, before they were treated with size, or other strengthening agent, in preparation for transport to England.

But, while preparations were being made for carrying out this scheme, most of the difficulties were removed by the fact that the Egyptian Government requested me to go out to Egypt in connection with the work of the Archæological Survey of Nubia, and it thus became possible to visit Mr. Quibell's excavations in person, to examine and measure all the material on the spot, to supervise the work of photographing and packing it for transmission to England. It was possible to do so much in the short time at my disposal, because Mr. Quibell and his trained workmen afforded every help, and Mr. Cecil M. Firth and his native photographic assistant, Mahmud Shaduf, of the Nubian Archæological Survey, volunteered to help. Mr. Firth took about a hundred and thirty photographs of the material. Every help was also given by the Egyptian Survey Department in the loan of instruments and other apparatus. Furthermore, the authorities at the Museum of the Royal College of Surgeons in London offered to take charge of and repair the material on its arrival, and to grant me every facility for its investigation.

Full notes and photographs were obtained of all human material rescued by Mr. Quibell, consisting of the remains of thirty-nine individuals of the Second and Third Dynasties, most of which is now safely housed in the Royal College of Surgeons' Museum. At the outset it may be stated that the material closely resembles the human remains of the Pyramid Age found in neighbouring sites of a somewhat later date. There are quite definite evidences of some racial influence alien to the Proto-Egyptian race; but the difficult problem is raised as to how much of the contrast in the features of the two populations—Upper Egyptian and Lower Egyptian at the Second and Third Dynastic Periods—is due to admixture and blending; and how much, if any, is due to the specialisation in type of the Delta portion of the Proto-Egyptian people.

The investigation also revealed some suggestion of attempts at mummification as early as the Second Dynasty—a fact of some interest, as the earliest undoubted case of mummification is referred to the Fourth or Fifth Dynasty (more probably the latter), and no

evidence has been obtained before of attempted mummification of a body which was not buried in the fully extended position.

While in Egypt I took the opportunity of comparing the Saqqara skulls directly with the type collection of Predynastic skulls in the Anatomical Museum of the Cairo School of Medicine, and also with skulls of the Fourth and Fifth Dynasties at Dr. George Reisner's excavations (for Harvard University and Boston Museum) at the Giza Pyramids.

For convenience of comparison I have followed the plan and used the notation explained in the Report on the Archæological Survey of Nubia (1910), vol. ii., p. 40.

Detailed Statement of the Results of Examination of the Human Remains.

2102 F.[3] Man about forty-five years of age, with well-defined alien traits.[4] Buried in a small mastaba with degraded stair placed alongside a big mastaba. A very big, broad, full ovoid calvaria, with large bregmatic bone and squarish orbits, and narrow high-bridged nose. The rest of the face and mandible are missing (that is, were not saved by Mr. Quibell). L. (maximum length of cranium in millimètres) 205, B (maximum breadth of cranium) 146, F.B. (minimal frontal breadth) 98, H. 135, L.O. 38 × 34.

2104 G. A man with a short and very perfect, well-filled ovoid skull, which does not conform to the Egyptian type; rounded orbits; long narrow nose; jaw of distinctly alien type. L. 176, B. 139, H. 137 (approximately), F.B. 90, T.F. 119, U.F. 73, Biz. 122, Interorb. 21, N. 50 × 23, R.O. 39 × 35, L.O. 36 × 34.

2104 J. A characteristic example of the type of skull (male) alien to Egypt, which was found at Giza and also at the Biga Cemetery at Nubia. It has large, obliquely placed, squarish orbits; prominent narrow-bridged nose, with very projecting sharp margins and long nasal spine; a broad face with the zygomatic arches curved strongly outward; a jaw with a wide chin; and a ramus which is narrow, moderately high, and has a big coronoid process. The skull is a short, broad, full ovoid; there is a straight line of brow and nose; very deep conceptaculæ cerebelli, associated with manifestation of an occipital vertebra. L. 174, B. 134, F.B. 93, H. 136, Biz. 130, T.F. 119, U.F. 71, C.B. 99, F.B. 91, Interorb. 22·5, R.O. 37 × 37, L.O. 37·5 × 36, N. 51·5 × 21·5, Big. 102·5. Femur, rough estimate of length, 486. One molar is carious, and there is widespread but slight periostitis of the leg-bones and pelvis. The pelvis and leg-bones are very big and massive.

2104 N.W. Woman, probably about twenty-eight years of age. The skull is a broad, flat ovoid (or beloid), with markedly sloping forehead, the profile passing without break into the nose ('Greek

[3] Distinguishing number of the grave in Mr. Quibell's Archæological Report.

[4] In using the term 'alien traits' I refer to features which are foreign to the Proto-Egyptian people as well as to the Brown Race in general. In most cases—as for example this instance—these foreign features, such as 'a very big, broad, full ovoid calvaria,' 'squarish orbits,' and 'narrow high-bridged nose' are distinctive of the Armenoid population of Western Asia.

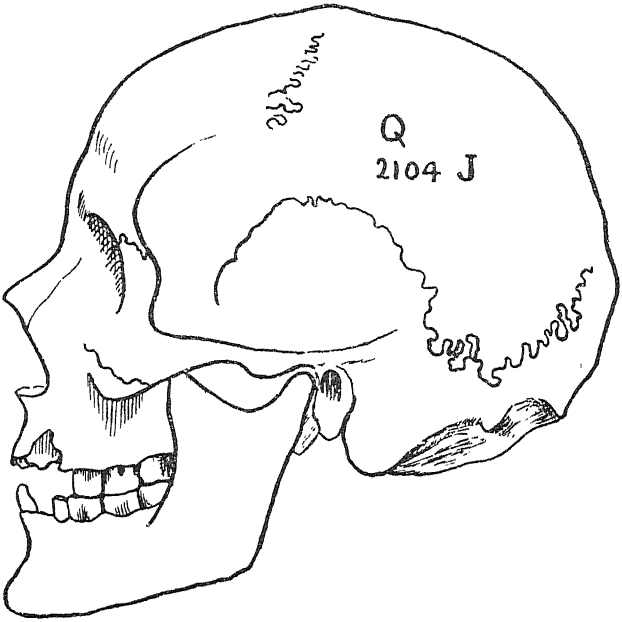


FIG. 1.

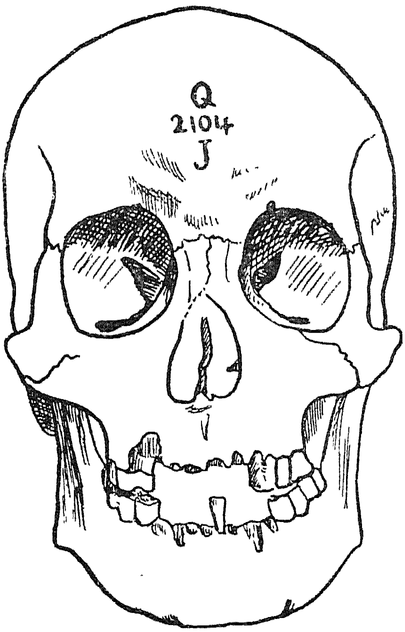


FIG. 2.

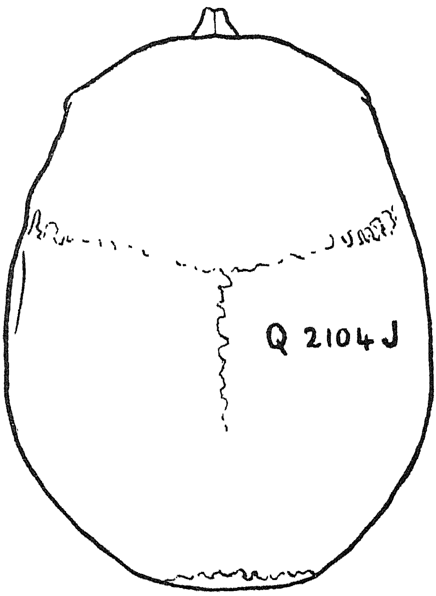


FIG. 3.

profile'); square orbits with rounded angles; nose moderately broad and not very prominent, but the nasal spine is large. In most respects the mandible conforms to the Proto-Egyptian type, but the ramus shows a tendency towards the form distinctive of the Biga population (see 'Report of the Archæological Survey of Nubia,' 1907-1908, vol. ii.). The teeth are perfectly healthy. The femur is small and slender, with slight flattening of the upper part of the shaft. The length of the right femur is 407, and the diameter of its head 38. L. 178·5, B. 138, F.B. 93, H. 132, Biz. 122, T.F. 120, U.F. 76, C.B. 102, F.B. 98, Interorb. 24·5, R.O. 39×34, L.O. 36×34·5, N. 55×27, Big. 87, Sym. 36.

2104 H.E. This is a man about twenty or twenty-one years of age, with a curious blending of the features seen in the skeletons of the man 2104 J. and the woman 2104 N.W., having the cranial features of the former and the facial traits of the latter. The skull is a moderately broad, well-filled ovoid, with a sloping forehead and a profile like 2104 N.W. The nose also resembles that of the latter, but is also curiously like that found in the Nubian people at the time of the Middle Kingdom. Its lower margins are rounded. The orbits are not quite so square as those of N.W., being almost elliptical and oblique. The teeth are perfectly healthy and unworn. The large size of the canines and incisors has produced slight prognathism. The left tibia is 306 in length; its epiphyses are just consolidating. L. 181·5, B. 141, F.B. 97, H. 138·5, Biz. 131, T.F. 120, U.F. 73, Interorb. 27, R.O. 40×33, L.O. 38×33, N. 52·5×26, Big. 86, Sym. 35.

2162. An elderly man with the coronal, sagittal, and lambdoid sutures almost completely closed. The teeth are well worn, but healthy, excepting for a 'perforation abscess'[5] at the root of the lower right first molar. There is, however, a considerable amount of tartar deposit on the teeth. The cranium is a big ovoid or beloid, with prominent superciliary ridges; small, flat, horizontal orbits; small, narrow, high-bridged, sharp-edged nose; a wide jaw, with broad chin, and a moderate ramus of alien form, with out-splayed angles. There is evidence of severe arthritis in the left temporo-mandibular joint. The face conforms to a type which is often seen in the Dynastic Egyptian. L. 193, B. 139, H. 136, F.B. 91, Big. 105, Sig. 52, T.F. 113, U.F. 69, Biz. 134, N. 54×25, Interorb. 26, L.O. 38×29, R.O. 37×30.

2116 N. This skeleton is probably a woman's. It conforms to the Proto-Egyptian type, the mandible being quite typical, and the skull a long ellipsoid, which is well filled. None of the cranial sutures show any sign of closing, although the teeth are moderately worn and encrusted with deposits of tartar. L. 181, B. 129, F.B. 93.

2146. A middle-aged or elderly man, with a full ovoid or beloid skull, with flattened occiput, somewhat rounded orbits, and moderately prominent nose. The coronal, sagittal, and lambdoid sutures are closing, and the teeth are worn down, and there are

[5] By this term I refer to an alveolar abscess, which is not due to dental caries, but originates by infection through the pulp cavity of a tooth, which has been exposed by excessive wearing-down.

several ‘perforation abscesses.’ There is thinning of the left parietal bone. L. 183, B. 139, H. 146, F.B. 93, U.F. 72, Biz. 130, N. 53·5×25, Interorb. 24, L.O. 38×33, R.O. 38×33.

2152. Middle-aged man, whose coronal and sagittal sutures are beginning to close. The teeth are well worn down, and there are four ‘perforation abscesses,’ that associated with the upper left second molar opening by a large perforation into the maxillary antrum. The jaw is a big, heavily built ovoid, with well-marked muscular impressions and prominent superciliary ridges. The orbits are flat and horizontal, the nose is narrow with a prominent high-bridged root. L. 188, B. 138, H. 138, F.B. 100, U.F. 69, Biz. 135, N. 49×24·5, Interorb. 24, L.O. 40×32, R.O. 40×33.

2170. A man whose coronal suture is beginning to close, and whose perfectly healthy teeth are only slightly worn. The skull is a big, well-filled ovoid, with sloping forehead and moderate superciliary ridges. The face is short and broad, with small, narrow nose and very flat orbits. The jaw is heavily built, but its form is Proto-Egyptian. L. 187, B. 141, F.B. 95, H. 138, Big. 131, T.F. 110, U.F. 67, Interorb. 25, R.O. 40×32, R.O. 40×33.

2170. A man whose coronal suture is beginning to close, and whose perfectly healthy teeth are only slightly worn. The skull is a big, well-filled ovoid, with sloping forehead and moderate superciliary ridges. The face is short and broad, with small, narrow nose and very flat orbits. The jaw is heavily built, but its form is Proto-Egyptian. L. 187, B. 141, F.B. 95, H. 138, Big. 131, T.F. 110, U.F. 67, Interorb. 25, R.O. 40×30·5, L.O. 38×30·5, N. 53×24.

2173 D. This is a child of nine or ten years, with a typical Proto-Egyptian pentagonoid skull.

2172 B. This is a woman of twenty years, or perhaps a little more, with a small head of Proto-Egyptian type, and well filled pentagono-ovoid form; the nose has a small horizontal, elliptical, flattened bridge; small mandible, with a very pointed chin: the zygomatic arches are laterally compressed. The teeth are in excellent condition and practically unworn. L. 178, B. 128, F.B. 85, H. 129, Biz. 116 (estimated), T.F. 111, U.F. 68, C.B. 98, F.B. 94, Interorb. 24, R.O. 38×27, L.O. 35×28, N. 46×24·5, Big. 82, Sym. 35, Sig. 45.

2172 E.B. A woman with very perfect, small, well-filled ovoid or ellipsoid cranium. The face might be Proto-Egyptian, but the large orbits and prominent-spined nose suggest alien affinities. The coronal suture is beginning to close. L. 173, B. 130, F.B. 90, H. 138·5, Biz. 121, T.F. 102, Interorb. 20, R.O. 37×32, L.O. 38×32, N. 48×23.

2172 α (? or β). This is a man with teeth moderately worn, but quite healthy. Sutures all open. Long pentagonoid cranium with a markedly *bombé* occipital. Prominent superciliary ridges thickening whole upper edge of orbits meet across the mid-line, overhanging the depressed and flattened root of the nose. Orbits flattened; nose wide; typical Proto-Egyptian jaw, with pointed chin and characteristic ramus. L. 194, B. 136·5, H. 141, F. 95, T.F. 107, U.F. 66, Biz. 130, N. 49×30, L.O. 38×30, R.O. 39×29, Interorb. 23·5.

2173. A woman about twenty-one years of age. Teeth healthy.

Typical Proto-Egyptian pentagonoid skull, with small, broad, flat-bridged nose (nasals fused), not separated by any depression from the frontal; oblique orbits, and typical high ramus and coronoid process of the alien type of jaw. L. 173, B. 133, H. 133, F. 92, T.F. 110, U.F. 67, N. 47 × 23·5, Interorb. 24, R.O. smashed.

2173 A. This is a woman with teeth well worn; left upper molars carious, abscesses at all upper molars. Temporal part of coronal suture closed, as well as the whole sagittal and part of lambdoid. Big broad ovoid head, with senile thinning commencing. Broad face with out-curved zygomatic arches and out-splayed angles of jaw. Long, very narrow nose, with prominent spine, but not very high bridge. Large square orbits, with deficient lateral walls. Left femur is severely affected by osteomyelitis, according to Professor Ferguson, of Cairo, who had taken the bone before I arrived at Saqqara. Large inflammatory excavation in front of right sacro-iliac joint. L. 183, B. 137, F. 96·5, H. 135, Biz. 133, T.F. 125, U.F. 80, Interorb. 23, R.O. 39 × 36·5, L.O. 40 × 37, N. 55 × 23, Big. 106.

2173 D. A woman's skull, almost edentulous, but all the sutures are still open. A broad, flat, beloid cranium associated with a small infantile face. L. 175, B. 138, F.B. 90, H. 117, Biz. 119, T.F. 101, U.F. 69, R.O. 37 × 30, L.O. 36 × 31, N. 52 × 22.

2175. A man with all upper incisors and right canine teeth gone, probably the result of some alveolar disease, leaving now a large hole about 27 mm. in diameter. The three principal sutures are closed. Has a large, lofty, well-filled ovoid skull. Face very long, narrow and ovoid, with Proto-Egyptian type of orbits; but small, narrow, high-bridged, sharp-margined nose. Pointed jaw with a high ramus, set at so oblique an angle that the sigmoid height cannot be measured. L. 185·5, B. 144, F.B. 96, H. 140, Biz. 131, T.F. 130, U.F. 73 (estimated), Interorb. 21, R.O. 41 × 32, L.O. 40 × 32, N. 50 × 24.

2262. A woman with a perfect set of healthy, almost unworn teeth; temporal part of coronal suture closed. A big broad pentagonoid skull with large alien jaw and rounded orbits. L. 189, B. 141, F.B. 95, H. 131, Biz. 122, T.F. 119, U.F. 72, Interorb. 24, R.O. 37 × 33, L.O. 36 × 33·5, N. 49 × 24.

This individual exhibits signs suggestive of some form of mummification having been attempted. If so, it is the earliest authentic evidence of such a practice. The skeleton was found completely invested in a large series of bandages—more than sixteen layers still intact, and probably at least as many more destroyed—ten layers of fine bandage (warp seventeen and woof forty-eight threads to the centimètre), then six layers somewhat coarser cloth, and next to the body a series of badly corroded, very irregularly woven cloth, much coarser (warp six and woof fourteen per centimètre) than the intermediate and outer layers. Each leg was wrapped separately, and there was a large pad on the perineum. The bandages were broad sheets of linen rather than the usual narrow bandages. The body was flexed, as was usual at this period.

In the wide interval between the bandages and the bones there was a large mass of extremely corroded linen, whereas the intermediate

and superficial layers of cloth were quite well preserved and free from corrosion, except along a line where the cloth was corroded to represent the rima pudendi—a fact of great interest when it is recalled that in the Fifth and probably the Fourth Dynasties it was the custom to fashion (in the case of male mummies) an artificial phallus.

The corrosion is presumptive evidence that some material (probably crude natron) was applied to the surface of the body with a view to its preservation. If so, this is the earliest body with unequivocal evidence of an attempt artificially to preserve or prevent decomposition in the soft tissues.

2262 N. (?) Woman aged twenty years of age. The teeth are healthy and almost unworn. Cranial sutures all open. Small infantile face of characteristic Proto-Egyptian type. Broad pentagonoid

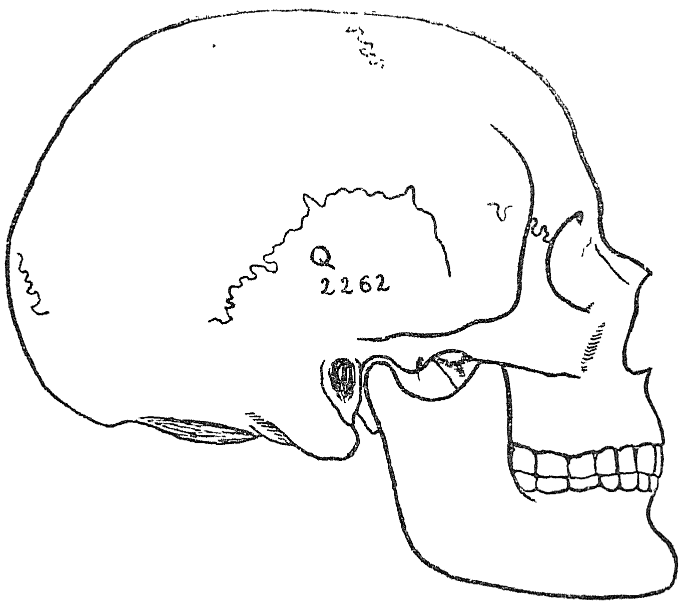


FIG. 4.

cranium and flat orbits. L. 185, B. 142, F.B. 83, H. 136, Biz. 124, T.F. 105, U.F. 63, Interorb. 21·5, R.O. 39·5×30, L.O. 37×30, N. 48×23.

2262 B.N. A small tomb containing a man aged about forty years. Teeth extremely worn; right lower molar carious; severe alveolar abscesses in upper jaw; only a few stumps left. Typical Proto-Egyptian pentagonoides, shading into ovoides. Low, very slightly oblique orbits; narrow nose with high bridge, very sharp margin and prominent spine. Semitic curve of nasal bones. Mandible with widely splayed angles. The face as a whole, while Proto-Egyptian in type, has a suggestion of the criminal Blemmye type in jaw, nose, and orbits—? a Sinaitic Arab. Three lower incisors (two right and one left removed), left zygomatic arch fractured, and rejoined with inward

bend. L. 189, B. 135, F.B. 97·5, H. 141, Biz. 130, T.F. 110, U.F. 70, C.B. 105, F.B. 93, Interorb. 23, R.O. 38·5×30·5, L.O. 39·5×31, N. 50×23, P. 53×37, Big. 108, H.S. 28.

2262 J.N. A man of about twenty years of age. Basilar recently closed. Teeth healthy and only slightly worn. Perfect Proto-Egyptian type. Long ovoid, fairly broad. L. 183, B. 137·5, H. 135, F. 89, U.F. 69, Biz. 120, N. 50 × 23, Interorb. 22, L.O. 36 × 29 (flat, horizontal, oblong), R.O. 38 × 30.

2196. This is a man whose coronal is beginning to close. Very full broad ovoid; large squarish orbits; very narrow, long, high-bridged nose; no jaw. L. 188, B. 137, H. 145, F. 91, U.F. 75, N. 55×23, Biz. 130 (curved out), Interorb. 20, L.O. 37 × 33, R.O. 37·5 × 31·5.

2187. A woman of about twenty-five years, with teeth quite healthy. Flattened beloid skull, with Proto-Egyptian jaw and horizontal flattened orbits. Small Proto-Egyptian nose and slight prognathism. L. 171, B. 140, H. 132, F. 90, Interorb. 22, L.O. 37·5 × 29, R.O. 38 × 29, N. 44 × 23, Biz. 120, U.F. 62·5, T.F. 105.

2256 N. A man almost edentulous, seven stumps flush with gum. Coronal, sagittal, and lambdoid closed. Big, well-filled ovoid head; oblique squarish orbits, and narrow prominent nose of alien type. L. 186, B. 138, H. 134, F. 104, U.F. 73, Biz. 132 (well curved out), Interorb. 24, L.O. 40×32, R.O. 37×33 (right occiput much more prominent), N. 54×24.

2256 S. A child of thirteen or fourteen years. Flat beloid skull 175 × 133, H. 133. Small elliptical horizontal orbits. Very narrow, sharp-edged, prominent nose.

2256 S. (2nd.) Child about seven years old. Long, narrow, pentagonoid skull. L. 176, B. 127.

2191. Woman. Coronal and sagittal sutures beginning to close. Metopic suture present. Teeth moderately worn and perfectly healthy, with slight tartar. Slender beloid skull. Fronto-nasal profile an unbroken line, sharp-edged nose of type suggestive of Giza (that is, from the necropolis of the Great Pyramids) aliens. L. 174, B. 130, H. 124, U.F. 65, N. 48 × 24, L.O. 39 × 31, F. 87·5, Interorb. 22.

No. ? A man aged fifty years; principal sutures closing, but teeth only slightly worn and quite healthy. Large beloid skull, but face of Proto-Egyptian type, with small pointed mandible. Nose probably of bulbous type (like that of King Mycerinus, as displayed in his statues). L. 189, B. 144, F. 97, H. 141, Biz. 129, T.F. 73, Interorb. 26, R.O. 40×32, L. 39 × 32, N. 50 × 28, Femur R. 468, head 45.

No. ? Man with small, regular, well-worn, perfectly healthy teeth. Temporal part of coronal suture closed. A somewhat effeminate skull with typical small-featured Proto-Egyptian face, but well-filled ovoid cranium. L. 179, B. 138, F. 96, H. 137, Biz. 123, T.F. 108, U.F. 70, Interorb. 25, R.O. 36·5×31, L.O. 36×30, N. 49·5×24.

2307. A skeleton, probably female, obtained from a large mastaba, but not certain. Coronal, lambdoid, and sagittal sutures closed. Well-filled ovoid skull. L. 185, B. 137, H. 126, F. 100.

2311 B. A woman forty-five years of age. Large, well-filled,

broad ovoid, almost ellipsoid cranium. Face of Proto-Egyptian type; moderately large, almost horizontal orbits; moderate nose; typical pointed Proto-Egyptian jaw; low ramus, with small coronoid. Vertical forehead, passing without interruption into line of nose. Femur R. 413, head 40. Femur small, with no pronounced features, slenderly built. Diameter of head, 40 mm. L. 181, B. 137, F. 93, H. 139, Biz. 127, T.F. 116, U.F. 73, C.B. 99, F.B. 92, Interorb. 24, R.O. 38 × 31, L.O. 40 × 31, N. 50 × 24, Big. 84, Sym. 30, Sig. 47, Cir. 510.

2313 W. A man with healthy but well-worn teeth; left upper

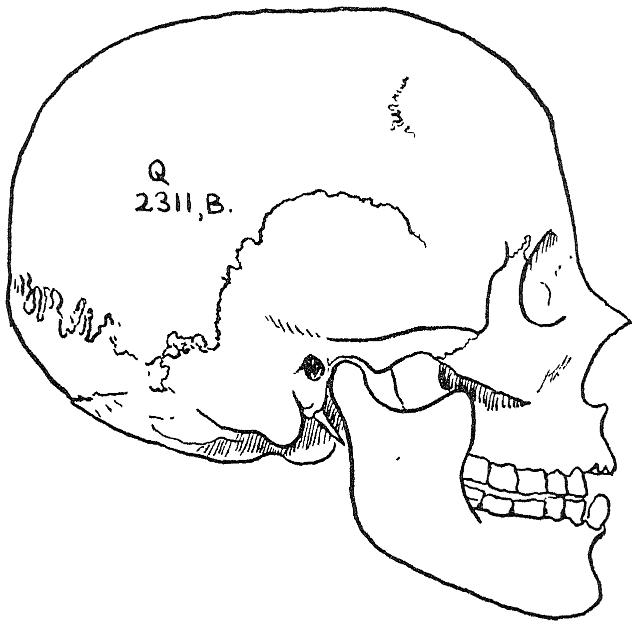


FIG. 5.

incisor missing and a curiously regular bevelled V-shaped hole in its place. Coronal and sagittal sutures closing. A big, high, ovoid cranium, with very narrow, high-bridged, prominent, sharp-margined, prominent-spined nose. Large squarish orbits; jaw with moderate ramus; beard on chin; race certainly alien. L. 186, B. 143, F. 92, H. 138, Biz. 130, T.F. 124, U.F. 76, Interorb. 21, R.O. 40×34, L.O. 39×35, N. 55×23.

2314 C. Man. Small pentagonoid skull of Proto-Egyptian type, cranium greatly thickened (parietal, 11 mm.).

2315 N.E. A man's skull, with coronal suture just beginning to close. Ovoid head with prominent superciliary margin; a small, narrow, sharp-margined, prominent-spined nose, otherwise typical small-featured Proto-Egyptian. L. 180, B. 139·5, F. 90, H. 143, Biz. 125, T.F. 119, U.F. 72, Interorb. 21·5, R.O. 39×31, L.O. 38 × 32, N. 50 × 25. Some tartar on the teeth, which are well worn.

An abscess, starting from the infection of the pulp cavity of the worn left upper molars, has eroded large holes in palate and into maxillary antrum.

2316. Probably a female about thirty-five years. Cranium is a well-filled ovoid, with flattened occiput, with fairly broad, sloping forehead. Moderately large squarish orbits, and small, narrow, and not very prominent nose. Teeth perfectly regular, and only very slightly worn. Mandible with somewhat curved body, and a narrow ramus, but not very high. In the temporal fossa there is a very marked prominence in the postero-lateral corner of the frontal. On the left side series of four lumbar vertebræ and the sacrum probably belonging to this body ankylosed by severe inflammatory process, which also affects the sacro-iliac joints, although there is no fusion of the bones in these joints. L. 174, B. 134, F. 96, H. 130, Biz. 123, T.F. 111, U.F. 70, C.B. 97, F.B. 95, Interorb. 26, R.O. 40 × 33, L.O. 39·5 × 34, N. 50 × 24·5.

2323 C. Woman with temporal suture closing and parietal thinning becoming apparent. Thick mass of tartar on teeth. Alveolar abscesses around upper molars. Very small head with typical Proto-Egyptian face, but rather well-filled ovoid cranium. L. 167, B. 129, F. 86, H. 129·5, Biz. 115, T.F. 105, U.F. 65, Interorb. 20, R.O. 35 × 30, L.O. 35 × 30, N. 49 × 23.

2338. Probably a man with very effeminate skull. The femur suggests masculine sex. Coronal suture closing. Large tartar deposits on the teeth; alveolar abscesses at the two lower molars on both sides. Typical Proto-Egyptian pentagonoid skull; large square orbits, but otherwise characteristic Proto-Egyptian face with suggestion of negroid influence. Very slender humeri, the right coronoid fossa perforated, anterior lamella only of left gone. Femur R. 443, head 44, L. 184, B. 132, F. 91, H. 134, Biz. 123, T.F. 118, U.F. 69·5, C.B. 95, F.B. 93, Interorb. 24, R.O. 39×36, L.O. 39×36, N. 50×23·5.

2344 A. Woman about forty years of age. Typical Predynastic narrow pentagonoid skull. Orbits were small, horizontal, and elliptical. Mandible was missing. Long and very slender femur with no outstanding peculiarities. Diameter of head 38. Femur R. 440, oblique. L. 175, B. 131, F. 83, H. 135, Biz. 120, U.F. 69, Interorb. 24, R.O. 35×31·5, L.O. 35×31·5, N. 40×24.

2347 C. A woman's cranium of Proto-Egyptian type, with sutures open. Facial skeleton missing. L. 180, B. 134, H. 131, F. 91.

2358. A woman with perfectly healthy, only slightly worn teeth. Temporal part of coronal suture closing. Perfect ovoid skull, with sloping forehead and uninterrupted line of forehead and nose. Rounded orbits and sharp-edged narrow nose of somewhat alien appearance. L. 180, H. 135, B. 137·5, F. 89, U.F. 67, Biz. 120, N. 49 × 23, Interorb. 20, L.O. 37 × 33, R.O. 38 × 33.

Skull found on stair north of 2376. Man. Teeth healthy and only slightly worn. Cranial sutures all open. Flattened beloid skull, with sloping forehead; jaw with broad chin and moderate ramus. Femur R. 445, head 42. Tibia curved and platycnemic. L. 182, B. 140, F. 97, H. 130.

2416. A man with coronal suture beginning to close and sagittal half-closed. Big broad pentagonoid skull, the face being Dynastic-Egyptian in type, with Proto-Egyptian jaw. Three lower incisors removed at some time. L. 187, B. 141, F. 99, H. 139, T.F. 120, U.F. 74, Biz. 137 (established), Interorb. 27, R.O. 38 × 31, L.O. smashed, N. 52 × 20.

2433. Sex uncertain. Temporal part of coronal suture closed. Mandible healthy and well worn. Left upper first molar and first premolar alveolar abscesses due to infection through the pulp cavities exposed by the wearing down of the teeth. Large abscess destroyed alveolus from second lower right molar to the premolars (inclusive). Small well-filled ovoid cranium. The nose has a somewhat flattened bridge, the jaw being rather a pronounced feature, typically Lower Egyptian. L. 171, B. 132, F. 90, H. 131·5, Biz. 128, T.F. 106, U.F. 67, C.B. 98, F.B. 94, Interorb. 22, R.O. 39 × 33, L.O. 37 × 31, N. 50 × 23 (moderately large orbits, not very oblique), Big. 86, Sym. 27, Sig. 52 (moderate outward curve of zygomatic processes).

The Significance of these Data.

In discussing the facts thus set forth I cannot refrain from expressing regret that it was not possible to examine each skeleton *in situ* in the tomb. For in removing human remains from tombs, not only does the material suffer considerable damage, but a great deal of the most valuable kind of evidence is destroyed. In this particular instance the loss of this opportunity is particularly regretted, because I feel sure important facts bearing upon the early practice of mummification might have been recovered.

In making these remarks I am not unmindful of the fact that Mr. Quibell removed the material from the tombs into his workroom with the object of facilitating my work and enabling me to do as much as possible in the limited time which I was able to spend upon this work at Saqqara.

Apart from supplying what is perhaps the earliest evidence of attempts at mummification (see the account of No. 2262 above), this group of remains has also provided the earliest known instances of symmetrical thinning of the parietal bones not due to senile changes. That this parietal atrophy was not due to old age is quite certain, because the best-marked case occurred in the skull of a young woman (No. 2323 C) who could not have been much more than thirty years of age. This is interesting in view of the fact that such parietal thinning has not hitherto been known to occur at so early a period, although it became exceedingly common in the Pyramid Age, two Dynasties later. Its causation seems to be associated with the habit of constantly wearing heavy wigs, which by pressure affect the blood supply of the parietal bones.[6]

Another interesting feature of the material discussed in this report is the rarity of dental caries, which became so common and wrought such appalling havoc in the successors of these people of Memphis a

[6] Elliot Smith, 'The Causation of the Symmetrical Thinning of the Parietal Bones in Ancient Egyptians,' *Journal of Anatomy and Physiology*, vol. xli., 1907.

few years later during the Pyramid Age. Alveolar abscesses are common enough, but they are not, as a rule, the result of dental caries, as I have explained above.

The contrast presented by this collection of human remains to those of the Proto-Egyptian population of the Predynastic period is so profound, and the alien features so widely diffused amongst them, that a fundamental problem is raised for discussion. This question is so large that I propose specially to consider its bearings in a separate communication to the Association.

The intimate blending of this Egyptian population with a people of foreign type and origin at so early a period as the Second and Third Dynasties points to the fact that we have to deal, not with a recent admixture, but one which must have been taking place for many generations before the time of the Second Dynasty. But we have no evidence to indicate whether the Western Asiatic element—for there can be no doubt as to the nature of the alien strain—had been percolating into the Delta gradually, or came more suddenly in larger volume possibly as a people already mixed to some extent with Egyptian blood in Syria or elsewhere.

The important result emerges from such considerations that the people who developed the wonderful and precocious civilisation of Egypt were not pure Proto-Egyptians. The growth of early Egyptian civilisation no doubt represents the gradual evolution of the ideas and the arts and crafts which we know to have had their origin among the Predynastic people of Upper Egypt; but their full fruition came only when the contact of peoples of diverse origin in Lower Egypt brought the influence of new ideas and new manners of thought—probably also a more virile type of intellect—to stimulate and help in the development of the Egyptian civilisation.

B. *The Human Remains of the Hyksos Period found in the Southern Part of the Kerma Basin (Sudan).*

At the end of 1913 I received from Professor George A. Reisner, who, working on behalf of Harvard University and the Boston Museum, had excavated a site at the south of the Kerma Basin, in the Dongola Province, a series of skeletons of the Hyksos Period. These bones were sent to me for examination, with the consent of the Archæological Committee of the Sudan Government and the approval of the Governor-General, Sir Reginald Wingate, whose interest in the anthropology of the Sudan is well known.

As only a part of the material has yet been sent to me, and as Dr. Reisner has not yet communicated the details of the archæological evidence, it would perhaps be preferable if I withhold my report until next year.

I may say that the tombs of the wealthier people contained the remains of typical Egyptians, such as we know to have lived in the Thebaid during the times of the New Empire; while the other tombs contained skeletons of Proto-Egyptian and Middle Nubian (C group) types. Although slight negroid traits are common, there is a surprising absence of the more obtrusive negro features.

Artificial Islands in the Lochs of the Highlands of Scotland.—Fourth Report of the Committee, consisting of Professor BOYD DAWKINS *(Chairman)*, Mr. A. J. B. WACE *(Secretary), and* Professors T. H. BRYCE, J. L. MYRES, *and* W. RIDGEWAY.

SINCE, owing to the meeting of the Association in Australia this year, reports have to be sent in at a much earlier date than usual, the Committee have so far little to record. The Rev. F. O. Blundell, the Committee's correspondent at Fort Augustus, continues to collect and tabulate information. He desires to thank the Committee for their assistance and for their encouragement in his investigations of a subject which, though full of interest, presents many difficulties that can scarcely be realised by those who have not taken part in the work.

By the courtesy of the Society of Antiquaries of Scotland, fifty reprints of the paper read before that Society, containing numerous illustrations, have been circulated amongst the correspondents of this Committee, and this has again stimulated interest in the subject. The Paper, which was compiled largely from the replies to the British Association inquiry, was printed in full in the 'Transactions' of the Society, and elicited numerous letters of congratulation on the results obtained by the Association. Mr. Gilbert Goudie, F.S.A.Scot., writes amongst others:—'May I be allowed to add that I have been much impressed by your paper on Artificial Islands in the "Proceedings of the Society of Antiquaries of Scotland"? These I had previously regarded as entirely exceptional and rare, but the numerous instances you adduce go far to show that they were almost the normal idea—quite a new conception which will influence me largely in looking at these things in future.'

One of the main objects of the Committee is to secure a suitable site for excavation. The artificial island in Loch Kinellan was provisionally fixed upon last year for excavation this year. Now Mr. F. C. Diack of Aberdeen has sent photographs and particulars of the 'Island' in the Loch of Leys, Banchory. The loch is now completely dry, and therefore this island is a much more suitable site for excavation than that in Loch Kinellan. The Secretary proposes to visit the site with the Rev. F. O. Blundell in July, and hopes to receive the permission of the proprietor, Sir Thomas Burnett, Bart., of Crathes, for the proposed excavation. It is hoped that the funds at the disposal of the Committee, together with a grant made by the Carnegie Trust to Dr. R. Munro for the excavation of the island in Loch Kinellan, will be sufficient for a preliminary excavation.

The Committee desires to be reappointed and that a grant of 5*l.* should be applied for at the next meeting of the British Association.

It will be necessary for a new Secretary to be appointed—Professor T. H. Bryce is suggested.

Exploration of the Palæolithic Site known as La Cotte de St. Brelade, Jersey, during 1914.—*Report of the Committee, consisting of* Dr. R. R. MARETT (*Chairman*), Dr. A. KEITH, Dr. C. ANDREWS, Dr. A. DUNLOP, Mr. G. DE GRUCHY, Col. R. GARDNER WARTON (*Secretary*), *appointed to excavate a Palæolithic Site in Jersey.*

Scheme of Operations.

THE Committee arranged with Mr. Ernest Daghorn, who had for the three previous years carried out the excavation of this site with signal success, that for the sum of 50*l.* (being the full grant authorised by the British Association) he should supply throughout the months of March and April 1914, viz., for forty-eight working days, the services of three experienced quarrymen, while himself superintending their labours; that he should bear the responsibility for all accidents; and that he should furnish whatever tools or other appliances might be required for the work. The Committee has to thank Mr. Daghorn for having amply fulfilled all that was expected of him. The men worked with a will, and great intelligence was displayed in the execution of orders.

Attention was exclusively directed to the main cave, already partially excavated by the Société Jersiaise in 1911 and 1912. Meanwhile it was hoped that it might be found to extend round the back of the ravine, up to now masked by talus, and so to be continuous with the smaller cave opposite, which Messrs. Marett and de Gruchy uncovered in 1913. Hitherto exploration of the main cave had been confined to the outer or western side, where the roof is somewhat lower and the pile of superincumbent débris consequently less. As the side contiguous with the back of the ravine is approached, the mass overlying the palæolithic floor and reaching up to the roof passes from about twenty-five to some forty feet of thickness; so that for every square foot of floor to be cleared an amount of material weighing approximately a ton has to be removed. It was now decided to tackle this heavier part of the task and, as far as might be possible in the time, to carry the clearing right across the mouth of the cave to whatever might prove to be its inner or eastern limit.

For the first three weeks the attack concentrated on the upper portions of the cave-filling, the extreme top being demolished by a successful piece of blasting which brought down some eighty tons. The ultimate aim being to open up the floor outwards from a line running parallel to the mouth about eighteen feet from it, it was necessary to cut back the higher portions of the detritus to the extent of another ten or twelve feet, so as to provide some sort of slope, and thus minimise the result of sudden downfalls. This was done without revealing either the true back of the cave or the supposed chimney through which the clay and rock-rubbish, other than what is due to roof-collapse, must have descended. It may be noted, however, that a tentative excavation on the further or northern side of the cliff into

which the cave penetrates brought to light a considerable fissure, about twenty feet higher than the level of what is to be seen of the cave-roof; and this may very well turn out to be the upper end of this hypothetical funnel. For the rest, these topmost parts of the cave-filling proved to be absolutely sterile, with the single curious exception that right at the back of the cave, some thirty-five feet above the floor, a piece of bone was noticed to jut out When this was with some difficulty rescued from its rather inaccessible position, it was found to have all the appearance of extreme antiquity, and is probably assignable to *Bos*. Presumably, therefore, it is contemporary with the cave-filling, and came down therewith from above.

It was calculated that it would be just possible with two months' work to carry a clearing about eighteen feet broad right across the mouth of the cave to its eastern side-wall, since its upper and visible portion, distant about thirty feet from the opposite side-wall, showed a perpendicular drop which might be presumed to extend indefinitely downwards. On April 8, however, it was discovered that this wall, along the whole breadth of the eighteen feet in process of clearance, was undercut, at a point about sixteen feet above floor-level, by a further cavity. To judge by the narrow section opened up, there is not less than twelve feet of additional penetration to be reckoned with on this side. Shielded as it is by its lower roof, this annexe would appear to be at once remarkably dry and free from shattering falls of rock. Thus it offers conditions more favourable to the preservation of bone than the high-domed cave on which it borders, and would be an ideal place in which to come upon human remains. This discovery led to a modification of the original plan, the breadth of the clearing being reduced to about ten feet, so as, consistently with thorough exploration of the portion of floor uncovered, to stretch forth a 'feeler' in this tempting direction. Nothing short of a fresh bout of excavation, however, supported by a grant no less substantial than the last, will enable the Committee to cope with this unexpected lateral extension of the main cave; not to speak of the rearward parts of the cavern which are likely to prove more or less prolific also.

In proceeding towards the eastern wall it was at first impossible to note any stratification in the gradually thickening floor owing to the large blocks distributed through it. At about twenty feet, as measured from the western side, there was, for the first time, clear evidence of some sort of stratification. For three feet above floor level there was a bed of thick ashes of a deep black colour. Above for about one foot succeeded an almost completely sterile layer. Then, for another two feet, occurred frequent implements in a layer of brownish clay, interspersed with slight traces of a darker matter. It was at first thought that the implements of the lower layer were rougher, and that, in particular, the typical Mousterian 'point' was absent. Subsequent observation, however, controlled by careful segregation of the finds from each layer, failed to bear out this view, some of the finest points (one of them, however, being worked on both sides, and in this way suggesting an older style of manufacture) being found in the lower bed. Of course a more detailed examination of the products

of the different layers may establish some sort of sequence in their forms. When the recess on the eastern side was reached the height of the implementiferous soil amounted to as much as twelve feet above the point taken to represent floor-level. At the very top of this bed were found three mammoth teeth and a large number of well-made implements. It is even possible to distinguish these highest portions as a third stratum, since in one place the top of the layer immediately above the sterile bed already mentioned was marked for about six feet by a thin line of almost pure sand. This sand was not such as might result from disintegration of the local rock, and its occurrence almost suggested that the inhabitants of the cave must at one time have indulged in the luxury of a sanded floor. This line of sand stood at about six feet above floor-level.

Osteological Remains.

At least 5,000 portions of bone, mostly very fragmentary, were discovered. It has been found possible only to submit these to the roughest preliminary examination. Dr. Andrews reports as follows on the selection of bones submitted to him at the British Museum:—

Hyæna Crocuta, var. Spelæa.—Portions of premolar teeth.

Canis Vulpes.—Maxilla.

Cervus Megaceros (Irish Elk).—Unworn upper molar, fragment of mandible with molars.

Cervus Elaphus (Red Deer).—Portions of jaw, with teeth.

Rangifer tarandus (Reindeer).—Numerous teeth, bones, and pieces of antler.

? *Capreolus Caprea* (Roe deer).—A tooth.

Goat or Sheep.—A tooth.

Bos primigenius.—Fragments of bones and teeth.

Equus.—Numerous teeth of a horse. The teeth are large, but it does not follow that the horse was.

Elephas primigenius (Mammoth).—Portions of a thin plated tooth.

Myodes torquatus (Arctic lemming).—Numerous lower jaws and bones.

A metatarsus of some species of *Grouse.*

This brings up the list of species (exclusive of varieties as in the case of *Equidæ* and *Bovidæ*) from six to thirteen, *Rhinoceros tichorhinus* having been found on previous occasions, and yields what may be described as a thoroughly representative Pleistocene fauna of the cold, or tundra, type.

Artefacts.

The amount of worked flint unearthed in the course of the recent excavation proved simply immense, over 3 cwt. of implements and chips (including hammer stones) having been extracted. It must be remembered that flint is not found *in situ* in the Channel Islands, so that it is perfectly certain that all flint found in the cave has been brought there by man. It is impossible briefly to convey an impression of the full extent of the material awaiting detailed study. This site will assuredly bear comparison with any other Mousterian site as

a source of a representative series of types. Very symmetrical 'points' adorned with the finest secondary chipping occurred to the number of several dozen. The largest measured 130 × 88 mm. Curiously enough, a small piece broken from the side of this specimen was recovered at a spot distant several yards away, though at the same level, the patina proving that the fracture was ancient. Some of the 'points' were of the graceful elongated type that has been termed 'hemi-Solutrian.' The most characteristic of these measured 97 × 53 mm. It is to be noted that the implement from the lowest layer worked on both sides was of this shape, measuring 115 × 52 mm. It is made of a piece of flint of a 'knotty' kind which may well have invited additional trimming. Several cases of double patination occur, the most noticeable being that of a well-formed 'point' measuring 70 × 50 mm., which, having first been blocked out in true Mousterian style, has afterwards had time to acquire a white patina (very similar to that characteristic of the Neolithic in Jersey, and thus possibly standing for some 5,000 years), and has been subsequently subjected to elaborate re-chipping along the edges. A 'point' beautifully worked in jasper, but, unfortunately, broken at the base, is something of a curiosity. For the rest, every known type of scraper abounds. Special notice may be taken of a frequent type in which the core has been utilised as a handle. A certain number of small pieces, the best examples measuring 50 × 22, 35 × 22, and 30 × 20 mm., bear a strong resemblance to arrow-heads, the more so as they have notched bases; though to ascribe the bow to Mousterian times may be somewhat unorthodox. One specimen, again, is of that 'rostrocarinate' type of which so much has lately been heard. Apart from the worked flint, there is a very interesting series of utilised pebbles, every variety of hammer stone being found. It seems to have been customary with the inhabitants of this cave to split pebbles, especially those formed of diabase, and to use the longitudinal sections as scrapers or polissoirs. By good fortune it was possible to re-constitute such a pebble out of three portions found in different parts of the lowest bed, at some distance from each other. Occasionally pieces of stone other than flint had been trimmed into the rough semblance of 'points,' the best example being of the hard sandstone (*grès Armoricain*) found in Alderney. A very interesting series has been provisionally constructed of granite implements. These occurred in the heart of the bed of ashes, side by side with flint implements of similar form, under such conditions as almost certainly to exclude the possibility of their being accidental splinters from the roof. Certain bone fragments showed clearly the signs of having been cut with a flint knife, and it is possible that they will have to be ranked as implements, one of them, for instance, whether by accident or design, making a very convenient spatula. It only remains to add that everything that can possibly be of human workmanship, including all the inevitable *débitage d'atelier*, has been carefully preserved and stored by the kindness of the Société Jersiaise in a special room, where the student can work over the whole material at his leisure, with every chance of constructing a truly classical series.

Acknowledgments.

The Chairman, Dr. R. R. Marett, directed operations from March 21 to April 22, inclusive, the Secretary, Colonel Warton, assuming responsibility for the rest of the time. Nine members of the Oxford University Anthropological Society, including Dr. F. C. S. Schiller and Mr. W. McDougall, F.R.S., took an active part in the work, while there were also many local helpers, most of them members of the Société Jersiaise. Special thanks are due to Mrs. Briard for the use of her car and for her personal assistance in the important matter of transport; to Mrs. Coltart and Miss Bayly for their help both in finding and in dealing with the finds; to Mr. G. de Gruchy, the proprietor of the site, who helped in the actual work of excavation for about a fortnight; to Captain A. H. Coltart (Exeter College), who actively superintended the work during its final stages, and took a leading part in arranging the material at the Museum; to Mr. B. de Chrustchoff (Lincoln College), who for a month inhabited a small cabin upon the site itself, and acted as custodian of the treasure; to Mr. T. B. Kiltredge (Exeter College), who was constantly at work for a month, and afforded great assistance in every way; to Mr. Emile Guiton, of the Société Jersiaise, who acted as photographer-in-chief; to Mr. Joseph Sinel, curator of the Museum of the Société Jersiaise, who took efficient steps to secure the preservation of the osteological remains; and last, but not least, to Dr. Smith Woodward and Dr. Andrews, of the British Museum, for the determination of the fauna represented by these remains.

Future Policy.

The Committee wishes to apply to the British Association for a grant of not less than the sum previously given, in order that the work may be continued without delay. It is well-nigh a certainty that a rich store of remains awaits excavation, and, indeed, that it lies exceedingly near to hand, more especially along the eastern side, where the hearth deposits are particularly rich. Any such grant will be devoted entirely to the work of removing the débris. All incidental expenses will be met by local contributions, as in the present case.

The Production of Certified Copies of Hausa Manuscripts.—Report of the Committee, consisting of Mr. E. S. HARTLAND *(Chairman)*, Professor J. L. MYRES *(Secretary)*, Mr. W. CROOKE, *and* Major A. J. N. TREMEARNE.

THE sum of 20*l*., placed at the disposal of the Committee in 1912, has been expended in payment of the printer.

Copies have been presented as follows: To the Committee for Anthropology, Oxford; the Syndicate for Anthropology, Cambridge; the Imperial Institute; the London School of Economics; l'Ecole d'Anthropologie, Paris; the University Library, Berlin; the India Office Library; Exeter College, Oxford; Christ's College, Cambridge; King's College, London; and to various missionary and other religious

societies where texts in Hausa will be accessible and useful to students. The usual copies have also been deposited in pursuance of the Copyright Acts. There remain three copies in hand which the Committee hope to distribute in a similar way shortly.

The Prehistoric Civilisation of the Western Mediterranean.—Report of the Committee, consisting of Professor W. RIDGEWAY *(Chairman)*, Dr. T. ASHBY *(Secretary)*, Dr. W. L. H. DUCKWORTH, Mr. D. G. HOGARTH, Sir A. J. EVANS, *and* Professor J. L. MYRES, *appointed to report on the present state of knowledge of the Prehistoric Civilisation of the Western Mediterranean with a view to future research. (Drawn up by the Secretary.)*

OUR knowledge on this subject has made considerable progress in recent years, though one of the main hypotheses—that of the advance of the so-called 'Mediterranean' race (to which several scholars attribute the megalithic civilisation of the end of the Neolithic and the dawn of the Bronze Age) from North Africa—has yet to be tested by further research in Tripolitania and Cyrenaica, which we may hope that Italian archæologists will shortly be able to undertake. In the meantime, the megalithic remains of Malta have been studied to some extent by the British School at Rome, though more work might be profitably undertaken there; a considerable number of dolmens are now known in Sardinia; and a new group of them has recently been found in the neighbourhood of Bari, in the south-east of Italy.

It would be important to study the intermediate links in the chain, which seems to connect the megalithic civilisation of the Western Mediterranean with that of our own islands: and the dolmens of Spain and Portugal might with some profit be further examined.

The Teaching of Anthropology.—Report of the Committee, consisting of Sir RICHARD TEMPLE *(Chairman)*, Dr. A. C. HADDON *(Secretary)*, Sir E. F. IM THURN, Mr. W. CROOKE, Dr. C. G. SELIGMANN, Professor G. ELLIOT SMITH, Dr. R. R. MARETT, Professor P. E. NEWBERRY, Dr. G. A. AUDEN, Professors T. H. BRYCE, P. THOMPSON, R. W. REID, H. J. FLEURE, *and* J. L. MYRES, *and* Sir B. C. A. WINDLE, *appointed to investigate the above subject.*

THE President of Section H, Sir Richard Temple, initiated a discussion at the Birmingham Meeting on the practical application of anthropological teaching in Universities. A report of this discussion was printed in *Man*, 1913, No. 102, giving the President's opening statement, extracts from letters from distinguished administrators and ethnologists, and an abstract of the speeches made by Sir Everard im

Thurn, Mr. W. Crooke, Lieut.-Colonel Gurdon, Dr. Haddon, Dr. Marett, and Professor P. Thompson.

A Committee was appointed by the British Association for the purpose of devising practical measures for the organisation of anthropological teaching at the Universities in the British Islands. With this committee was associated a committee appointed by the Council of the Royal Anthropological Institute. These committees met in joint session at the Institute, under the chairmanship of Sir Richard Temple, and passed the following resolutions: '(*a*) It is necessary to organise the systematic teaching of Anthropology to persons either about to proceed to, or actually working in, those parts of the British Empire which contain populations alien to the British people. (*b*) The organisation can best be dealt with by the collaboration of the Royal Anthropological Institute, the British Association, and the Universities, with the support and co-operation of the Government, the Foreign Office, the India Office, the Colonial Office, and the Civil Service Commissioners. (*c*) It would be well for the organisation to take the form of encouraging the existing Schools of Anthropology at the Universities and the formation of such schools where none exist. (*d*) As laboratories, a library, and a museum, readily available for teaching students, are indispensable adjuncts to each school, it is desirable to encourage their formation where they are not already in existence.'

By the courtesy of the Master and Wardens of the Worshipful Company of Drapers of the City of London, a conference to consider the findings and recommendations of the Joint Committee was held in the Hall of that Company on February 19, 1914. The President of the Conference was the Right Hon. the Earl of Selborne. A large number of representatives of various Home and Colonial Government Departments, Universities, Societies, as well as politicians, administrators, and others, were present or sent letters of regret at their inability to be present at the Conference, and expressing their sympathy with the purpose of the Conference. A full report of this Conference will be found in *Man*, 1914, No. 35.

In November 1913 Sir Richard Temple addressed the Indian Civil Service students at Exeter College, Oxford. In February 1914 he published a pamphlet entitled 'Anthropology a Practical Science,' which included his Birmingham Address (1913), an Address delivered in Cambridge in 1904, and extracts from that given at Oxford (1913). In March he addressed the American Luncheon Club, and also the Sphinx Club, both mercantile institutions, on Anthropology in its 'business' aspects. And he has engaged to do the same at the Merchants' Luncheon Club at Hull.

It has not yet been possible to place the findings of the Conference before the Prime Minister, whose time has been, and is still, taken up with urgent matters of State. An endeavour to secure an audience with the Prime Minister will be made when an opportune moment arrives.

The Ductless Glands.—Report of the Committee, consisting of Professor Sir EDWARD SCHÄFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A. B. MACALLUM, Dr. L. E. SHORE, *and* Mrs. W. H. THOMPSON. (*Drawn up by the Secretary.*)

MR. A. T. CAMERON has continued his investigations on the presence and function of iodine in different tissues. Examination of the thyroids of the elasmobranchs *Scyllium canicula* and *Raia clavata* gave positive results, those for female *Scyllium* thyroids (1·16 per cent.) being higher than any previously reported.[1] Examination of the thyroids of the dog-fish *Acanthias vulgaris*, of the frog, of the alligator, and of the pigeon gave positive results, the variations found being traceable to variations in diet. Comparison of the iodine content of thyroid and parathyroid tissue in the dog gave such marked differences as to warrant the assumption that the parathyroid is not concerned with the production of iodine compounds, and, therefore, as far as these are concerned, that there is a differentiation of function between the two glands.[2]

A wider investigation has shown, in comparison with data previously published by others, that iodine is an almost invariable constituent of all organisms, plant and animal, the amount depending on the diet and medium of the organism. With higher development there is greater specificity of the tissue concerned in storing iodine, until in the vertebrates no tissue except thyroid contains appreciable quantities. Thymus especially has been examined in a large number of species, with negative results. All normal thyroids contain iodine, the amount varying with the diet, and between the limits 0·01 and 1·1 per cent. (dry tissue). Other observers have shown previously that sponges and corals (besides many algæ) contain quantities of iodine comparable with that in the thyroid. Three other types of tissue have been found in marine organisms which contain amounts of iodine over 0·1 per cent. (dry tissue) viz.: the horny tubes of Eunicid worms, the external cutaneous tissues of the 'foot' of the horse-clam, and the test of a tunicate. Further work will be carried out to determine the type of iodine compound in these tissues, with a view to throwing further light upon the type of iodine compound in the thyroid. The above results are in course of publication.

Mr. Cameron is also engaged in work on the effects of feeding iodine compounds (and thyroid) on the amount of iodine present in the thyroid gland, with a view to determine the rate of increase or diminution. These results are not yet ready for publication.

The Secretary has been engaged upon various problems connected with the ductless glands. The effects of varying conditions upon the histological structure of the thyroid and parathyroid have been investigated in a preliminary fashion, but the results are conflicting and difficult to interpret. The variations in structure in normal thyroids

[1] *Biochem. J.*, **7**, 466, 1913. [2] *J. Biol. Chem.*, **16**, 465, 1914.

are so great that the effects of feeding, drugs, &c., cannot be summarised in a definite manner.[3]

The pharmacodynamics of different extracts have also been studied. Among other facts to which attention will be called in subsequent publications it may be mentioned that large doses of adrenin by no means always interfere with the normal action of the vagus, that the rise of blood-pressure due to injection of adrenin is of a double nature, and that comparatively small doses of the last-mentioned drug frequently cause an unexpected fatal result in dogs.

The effects of adrenin and thyroid extracts upon the activity of the vagus have led to an inquiry as to the effect of hormones upon vaso-motor reflexes, and owing to the unsatisfactory accounts given in the majority of books as to the actual facts in connection with these reflexes, it has been necessary to extend the inquiry so as to include a consideration of the vaso-motor reflexes in general. So far, the only hormone which appears to give any interesting results is the extract of pituitary, the effect of injection of the extract being to change the nature of the reflex, so that in cases where, for example, stimulation of the central end of the sciatic produces a fall of blood-pressure, after injection of pituitary extract a similar stimulation produces a rise.

This work is nearly ready for publication.

The Committee desire to be reappointed with a grant of 40*l*.

Calorimetric Observations on Man.—Report of the Committee, consisting of Professor J. S. MACDONALD (*Chairman*), Dr. F. A. DUFFIELD (*Secretary*), *and* Dr. KEITH LUCAS, *appointed to make Calorimetric Observations on Man in Health and in Febrile Conditions.* (*Drawn up by the Secretary.*)

IN furnishing a report upon the calorimetric work undertaken during the past year, it is necessary to refer to a paper published by Professor Macdonald and printed in the 'Proceedings of the Royal Society,' B, vol. 87, 1913, and to a communication to the Physiological Society, May 1914. The commencement of the first paper, containing a description of the apparatus and of the method of procedure followed in these experiments, may be omitted here, since these have been included in previous reports of this Committee. The latter part, which is the collected and digested results of a very large number of experiments made upon a variety of individuals, forms a large part of this report.

The experiments all through have been carried out by Professor Macdonald with the apparatus and in the manner already described by himself in the earlier reports. The subject, shut up within the calorimeter, was made to perform a definite measured amount of mechanical work upon the cycle. The degree of work was varied in different experiments, and from the data of these heat-production

[3] See discussion, *Lancet*, 1914 (March and April), by Bell, McGarrison, Chalmers, Watson, and Vincent.

figures have been obtained which fall into four groups corresponding to the grades of mechanical work done. It has been found that these results may be expressed by a constant multiplied by a function of the subject's weight, which varies with the amount of mechanical work performed in the different groups, *i.e.* ·02, ·03, ·07 and ·09 h.-p.

$$\begin{array}{llcl} \text{Group A—Heat-production} & & = & K_a W^{4/8} \\ \text{,,} \quad \text{B—} & \text{,,} & = & K_b W^{2/3} \\ \text{,,} \quad \text{C—} & \text{,,} & = & K_c W^{1/3} \\ \text{,,} \quad \text{D—} & \text{,,} & = & K_d \end{array}$$

From these results it is evident that the weight becomes less and less of a handicap as the mechanical work increases. And, to carry this a stage further, the query arises as to the likelihood of the weight becoming a positive advantage at a still higher grade of mechanical work.

The communication to the Physiological Society contains a formula for one of the subjects cycling at a revolution rate varying from 40 to 98 revolutions per minute, and performing external work against a brake varying in different experiments from 0 to 73 calories per hour—

$$43V^{\frac{V}{251}} + \frac{56\cdot3}{W^{2/3}} \times \text{work in Kals. per hour} = \text{Kals. per hour.}$$

The first part of the formula represents the heat-production associated with the rate of movement 'V,' and is the same no matter what the value of the external work performed by the movement. The second is the 'coefficient of efficiency' multiplied by the external work done, and fully represents the heat-production associated with the performance of external work. It will be noticed that this coefficient of efficiency is represented as varying inversely with the two-thirds power of the subject's weight, and that the 'efficiency' which is its reciprocal therefore varies directly with this value. This has been found universally the case in the data from all the remaining subjects, and explains the fact that in the heavier work experiments the results become independent of the subject's weight, if consideration is paid to the other fact, also elicited from these data, that the heat-production associated with movements *per se* (irrespective of the mechanical work performed by them) varies, on the other hand, directly with the function of the weight. In fact the total energy transformation is the sum of the two factors, one due to the subject's movements *per se* varying directly, the other due to performance of mechanical work in the course of these movements varying inversely as the subject's weight; but in neither case in a simple linear fashion. The general formula given (Proc. Physio. Soc., March 1914), is

$$87WV^{\frac{VW^{\frac{1}{3}}}{1878}} + \frac{56.3}{W^{\frac{2}{3}}} \times \text{work.}$$

The first fraction is probably expressible in the following form—$KWV^{\frac{K'V}{v}}$, where 'v' is the natural rate due to the 'pendular character' of the limb movements, and V is the particular rate imposed in each experiment.

Professor Macdonald also finds analogies between these results and those of walking experiments described by Douglas and Haldane in 'Phil. Trans.' B, ciii., p. 245. A full consideration of the matter will be found in a paper communicated, June 1914, to the 'Proc. Roy. Soc.' on the 'Mechanical Efficiency of Man.'

The section of the work dealing with the respiratory changes has also been continued during the past year. A number of experiments have been performed in which the respiratory interchange of a man, doing a measured amount of mechanical work upon a cycle in the calorimeter, has been investigated. The calorimeter is ventilated by means of a stream of air drawn through it at a uniform rate by a pump and measured by a meter placed on the distal side of the latter. All three are connected by tubing, through which the air flows, and the air as it leaves is sampled by suitable means every ten minutes. The samples thus obtained are examined by the gas-analysis apparatus devised by Dr. Haldane, and the carbon dioxide and oxygen percentage determined. The carbon dioxide figures, when plotted against the time on squared paper, take the form of a curve rising steadily to a horizontal asymptote.

In order to understand the figures thus obtained it was obviously necessary to inquire into the question of storage of gases within the calorimeter, and to do this a number of calibration experiments (17 in all) were made, in which a stream of carbon dioxide, measured by a gas-meter and generated by a modification of the apparatus described in a paper by Young and Caudwell ('Soc. Chem. Ind.,' March 1907), was passed into the calorimeter at a uniform rate, and the ten minutes' samples examined in the manner described in the experiments on the human subject. Attempts were then made to discover the relation which exists between the curve of the carbon dioxide in the leaving air and that of the carbon dioxide introduced from the generating apparatus; but so far the results appear so complicated that no definite relation has been arrived at. However, quite recently Mr. G. H. Livens, M.A., Lecturer on Mathematics to the University, has rendered most valuable assistance towards solving this problem. A fairly accurate empirical formula has been obtained from the actual readings, but it is not of such good agreement with the theoretical formula as is desired, and further experiments are being made to detect the cause of the discrepancy.

Owing to the appearance of a considerable error in the readings of the large meter used for measuring the volume of the air-flow through the calorimeter, it became necessary to replace it by a water-meter supplied by Messrs. Parkinson and Cowan, Ltd. Also, a large number of tests were made, both in the Physiological Laboratory and through the courtesy of the Sheffield Gas Company at their test-room, on the small meter which is used for measuring the volume of carbon dioxide introduced into the calorimeter in the calibration experiments mentioned above. I am now certain that the error in our estimation on these accounts is well under 2 per cent.

The Effect of Low Temperature on Cold-blooded Animals.—Report of the Committee, consisting of Professor SWALE VINCENT (*Chairman*) *and* Mr. A. T. CAMERON (*Secretary*). (*Drawn up by the Secretary.*)

MR. A. T. CAMERON has continued the experiments of Cameron and Brownlee on frogs communicated in the last report, and has arrived at the following conclusions:—

(1) The death-temperature of *R. pipiens* from cold is $-1{\cdot}25^\circ \pm 0{\cdot}15^\circ$ C.

(2) There is no climatic adaptation, nor any periodic adaptation due to hibernation, in *R. pipiens.*

(3) The cause of death is a specific temperature effect on the co-ordinating centres in the central nervous system. Those controlling lung-respiration may be specially concerned.

(4) Frogs surviving degrees of cold such as those occurring during a Manitoban winter do so below the surface, near the margin of springs, and are themselves never subject to temperatures below the freezing-point of water.

(5) There seems to be a slight variation in the death-temperature from cold, of different species of frogs, amounting to some tenths of a degree Centigrade.

(6) Frogs heated rapidly to normal room-temperature from a temperature just below the freezing-point of their body-fluids (and not itself capable of causing death) are thrown into a peculiar hypersensitive condition, in which cessation of lung-breathing takes place for long periods.

These results are deduced from experiments with *R. pipiens* from Manitoba, Minnesota, and Illinois, with *R. clamitans* from Minnesota, and with *R. sphenocephala* from C. Carolina. The experimental details will be published elsewhere. The Committee do not wish to be re-appointed.

Miners' Nystagmus.—Interim Report of the Committee, consisting of Professor J. H. MUIRHEAD (*Chairman*), Dr. T. G. MAITLAND (*Secretary*), Dr. J. JAMESON EVANS, *and* Dr. C. S. MYERS, *appointed to investigate the Physiological and Psychological Factors in the Production of Miners' Nystagmus.*

Factors concerned: (*a*) Internal; central and peripheral. (*b*) External.

Two features have long been admitted to be provoking agencies in the production of miners' nystagmus—an external factor, defective lighting, and an internal or peripheral factor, viz., muscular strain. The former, defective lighting, is found to be the more important, and our examination led us to conclude that where this factor is in greatest evidence there we find the greatest incidence of cases. Miners' nystagmus is a disease limited practically to coal-mining, and, further, it is associated with the use of lamps of small illuminating power, such as the Davy

or its modifications, so that it is rare, even in coal-mines, to find cases of nystagmus where more powerful illuminants such as candles and electric lamps are used. Moreover, the great absorption of light by the coal-surface diminishes the illuminating value of the lamp employed. This absence of reflections from walls, floor, and ceilings interferes with clear visualisation, since direct rays are never so satisfactory as diffuse rays. The other factor mentioned above—muscular strain, especially of the elevators of the eyeballs—is also taken into consideration, notwithstanding the difference of opinion on the importance of this. Snell has collected several cases of nystagmus which, as in the case of compositors, has followed strain in this way, and we have ourselves found that there is a larger number of cases of miners' nystagmus associated with 'holing' than in any other occupation underground—under conditions, therefore, which demand an awkward posture with straining of the head and eyes. Other sources of peripheral irritation are opacities of the media, errors of refraction, pigmentary and other ocular defects, which tend to produce or aggravate nystagmus by either modifying illumination or by causing muscular strain or by interfering with the direct rays on the fovea.

Taking all these factors, however, into consideration—factors which are generally acknowledged—the fact remains that, working under similar conditions of illumination and strain, a large percentage of miners do not develop nystagmus, and it is our object to find out what is the decisive factor. Admitting the external factors in those who develop nystagmus to be more or less constant, admitting the occasional possibility of peripheral factors such as those above mentioned, there remains some factor unaccounted for which explains the selection of certain miners for this trouble. At this stage of our inquiry, however, we investigated what seemed to us a neglected field—the relative sensibility of the retina in the foveal and in the perifoveal regions—and for this reason. The peculiar modifications which the dark-adapted eye undergoes might bring about a still further interference with the illumination by a reactive function on the part of the percipient.

A consideration of the conditions of work in the coal-mine suggested very strongly the importance of the possession by the miners of delicate vision sensibility. Before dark-adaptation could be fully developed the miner at his first entry into the pit would have to strain his vision under the most trying circumstances to avoid roof obstacles as he made his way to his work. Such a strain would display itself in the muscles chiefly involved, such as the elevators of the eyelids and of the eyes. It is interesting clinically to find the initial symptom complained of is a heaviness of the lids.

At work on the coal-face the miner with his eyes on the coal-surface would be subjected only to a few reflected rays from smooth facets of coal and some little diffused light from the coal-surface generally. Very dim light would bring out the latent differences in the visual sense, such as the differences of acuity between foveal and perifoveal vision. If the rays were too feeble to excite foveal sensation they might yet stimulate perifoveal sensation.

Our theory regarding this particular feature of the eye was that a

perifoveal sensation, in the absence of foveal sensation, or a perifoveal sensation of greater intensity than a foveal sensation, would excite a fixational or movement reflex. This would bring the exciting point in the marginal field on to the fovea, and would then either cease altogether to excite sensation or would be so diminished in intensity as to lay the eye open again to marginal stimulation. With a central stigma, a neurasthenic diathesis, there would be present all the material for the development of a habit spasm.

A large number of observations were made on students, assistants, and ourselves with a piece of apparatus described in the appendix. This apparatus was arranged to present a spot of light the intensity of which was controllable. The open eye was directed on this spot while the room was in full daylight, and then the room was suddenly plunged into darkness. At the end of five seconds the subject was examined as to his ability with direct vision to perceive this faintly illuminated spot, its intensity rapidly altered until the subject was only just able to perceive it. The time for this, the minimum visibile, usually took about five seconds, and the degree of illumination was remarkably constant in all these cases, so much so that we were able to fix on this degree of light intensity as our zero. The direct vision was contrasted with indirect vision, the subject being directed to look slightly away from the spot of light, which at once appeared to become more vivid. The intensity was then diminished until here again the spot was only just discerned, and so we obtained a minimum vision visibile for indirect or perifoveal vision.

At intervals of two and a half minutes the minimum visibile.was estimated for both fovea and perifovea, and we were able to represent in graphic form the increasing sensibility of the retina to faint illumination. In general the dark adaptability of fovea and perifovea increased rapidly up to the end of half an hour, less rapidly up to the end of two hours; arriving then at its maximum sensibility it remained stationary. The perifovea throughout this development of dark adaptation not only retained its primary advantage, but slightly increased that advantage up to the limit of change. In our experience in the coal-mines we never, however, felt that the maximum amount of sensibility was ever in demand, and while the light was indeed feeble enough to be excessively irritating to our unaccustomed eyes, yet nowhere did we find working conditions approaching our experimental conditions. Was the miner's eye differently equipped from our own, did it possess a greater adaptability through use and habit?

This led to an examination of the dark-adaptability of miners who had been afflicted with nystagmus, and here we found without exception a totally unexpected condition, yet one which now rendered plausible our fixational hypothesis. Instead of finding a greatly increased adaptability as a result of long use and cultivation of the eye in the dark, we found that in this respect it was greatly inferior to the 'normal' eye. In the first place the 'zero' was not perceived until after about five minutes of exposure to the dark, and then once perceived it remained without an appreciable development through the two hours' experiment. This peculiarity on the subjective side amounted to the same thing in

its effects as a modification of the external factors of the illumination, so that the differences observed in the normal eye, under the experimental condition described above, might in the case of the miner come into operation under the condition of his work owing to the altered sensational values following retinal insensitiveness. The fact is that the theory of 'fixational reflexes' might yet be true of the behaviour of the miner's eye in the coal-mine.

The conclusion of the research so far then seemed more and more to lay stress on the one well-recognised agency, that of illumination, and that insensitiveness of the retina really amounted to the same thing as an absolute decrease in the illuminant.

There remains for examination the actual excursion of the eye, and an examination into the nervous system of the afflicted miner.

Since this was written an examination of unaffected miners has been made, with the result that there is no appreciable difference between their dark-adaptability and what we describe as the normal.

The Apparatus for estimating the Minimum Light Sensibility in the Process of Dark-adaptation.

It consists of an oblong box, the front of which is pierced by a round hole with a diameter of 20 mm., which is covered by an opal disc. At the back of the box exactly facing this aperture is a sheet of white paper which reflects light thrown upon it on to the disc. At the side of the box is another aperture into which a tube nearly 2 m. long fits. This tube carries within it a small 2-volt lamp which can be moved quite freely from end to end. The light from this lamp is thrown on a mirror so placed that it reflects this light on to the sheet of paper, which then reflects it on to the disc. It was only in this way the light could be sufficiently diminished to obtain marginal stimuli.

After a number of experiments we arbitrarily decided upon our zero—that is, the light that could be only just perceived five seconds after the room was plunged in darkness. At intervals of two and a half minutes the subject was tested again, and the lamp was gradually moved away from the box until the subject failed to perceive the disc.

The Investigation of the Jurassic Flora of Yorkshire.—Report of the Committee, consisting of Professor A. C. Seward (*Chairman*), Mr. H. Hamshaw Thomas (*Secretary*), Mr. Harold Wager, *and* Professor F. E. Weiss.

This year attention has been concentrated on the plant beds on and near Roseberry Topping, North East Yorkshire, more especially on the Thinnfeldia beds. A careful search was made for the reproductive structures of *Thinnfeldia*, and this was rewarded by the discovery of numerous associated seed-like bodies, whose structure has yet to be investigated, and which may, perhaps, prove to belong to this plant. A new example of a *Williamsoniella* flower-bud was found, which is of interest in greatly extending the range of this form. Some fruits and seeds, probably referable to the provisional genus *Caytonia*, were also discovered, though they were previously known only from Gristhorpe. One or two new forms were found, and many duplicates of the more interesting species were collected. It is not proposed to continue field-work and collecting in the future on the same scale as

during the past three years until the existing collections have been fully investigated.

The Committee does not seek re-appointment.

The Vegetation of Ditcham Park, Hampshire.—Interim Report of the Committee, consisting of Mr. A. G. TANSLEY *(Chairman)*, Mr. R. S. ADAMSON *(Secretary)*, Dr. C. E. MOSS, *and* Professor R. H. YAPP, *appointed for the Investigation thereof.*

SINCE the date of the last report a large number of experiments have been carried out with evaporimeters. Especially, a large series of simultaneous readings have been taken, covering a considerable period, from instruments placed in various positions in beech-woods, coppices, and in open grassland. Several of the results suggest further lines of experimentation and research, but a much larger number of readings must be obtained before any generalisation can be enunciated. The evaporimeter readings have been run concurrently with a series of readings of wet and dry bulb thermometers, and also of maximum and minimum thermometers which have been placed in association with the evaporimeters.

The work on soils has commenced, but so far has been mainly preliminary. Experiments have been made on soil temperatures, especially in relation to exposure, drainage, woodland canopy, &c.

The general preliminary mapping of the various associations composing the area has been completed, and an analysis of them has been made from the topographical and floristic standpoints as a basis for experimental work in the coming season. In this connection special attention has been paid to the successive changes occurring after coppicing till the re-forming of the full canopy, and also to the question of the recolonisation by trees of cleared areas and grasslands. Data have been collected which serve as a starting-point for a more detailed study.

The areas enclosed against rabbits, &c., have also been under observation, and the changes occurring have been examined and recorded.

The Committee asks to be reappointed, without a grant.

Experimental Studies in the Physiology of Heredity.—Report of Committee, consisting of Professor F. F. BLACKMAN *(Chairman)*, Mr. R. P. GREGORY *(Secretary)*, Professor W. BATESON, *and* Professor F. KEEBLE.

THE grant of 30*l*. has been expended in part payment of the cost of experiments conducted by Miss E. R. Saunders, Mr. R. P. Gregory, and Miss A. Gairdner. Miss Saunders' experiments with stocks have had for their main objects:—

(1) The investigation of the condition known as half-hoariness and

its relations to the glabrous and fully-hoary forms. A new half-hoary race, which has been obtained after some difficulty, has made it possible to design a complete series of experiments, which is now in progress.

(2) The further study of the gametic coupling already shown to exist between the factors for double-flowers and plastid-colour. This investigation promises to give results of great interest, but a further generation must be raised before a statement can be made.

(3) A result of some interest is the discovery that the double-flowered plants, at least in some strains, have a more rapid and vigorous growth than the singles. It is thus possible, by means of selection based on this difference, to obtain a far higher percentage of doubles in the flower-bed than would be expected from the normal output of doubles by a double-throwing single.

(4) A beginning has also been made with the work of obtaining a complete series of types of known factorial constitution, so that a supply of material may be available for testing the view which has been put forward as to the inter-relations between the factors determining hoariness and sap-colour.

Experiments with foxgloves have been designed for the investigation of a curious condition of partial hoariness, as well as for observations on the range of variability in the *heptandra* form.

Experiments by Mr. Gregory with *Primula sinensis* have been designed chiefly with a view to the investigation of the cytology and genetics of certain giant races, which have been shown to be in the tetraploid condition; that is to say, they have $4x$ (48) chromosomes in the somatic cells and $2x$ (24) chromosomes in the gametic cells, whereas in the diploid races the numbers are $2x$ (24) and x (12) respectively. These experiments have given results of very great interest, which may be briefly summarised by saying that the reduplication of the chromosomes has been found to be accompanied by a reduplication of the series of factors. An account of this work has been published in the 'Proc. Roy. Soc.,' B., Vol. 87, p. 484, 1914, and it is hoped that a further statement will be made at the meeting of the British Association in Australia. Further experiments with these tetraploid plants are designed especially to investigate the phenomena of coupling and repulsion between certain factors. These experiments promise to yield results of very great interest, both as regards the genetics of tetraploid plants and as regards cytological theory as to the possible relations between factors and chromosomes.

In the experiments with the ordinary diploid races, an interesting case has been discovered in which the coupling between the factors for magenta and green stigma is on the system 7 : 1; whereas in a very large number of other experiments the coupling (or repulsion) between these factors is of a very low order, apparently less than 3 : 1.

A paper is in the course of preparation, and will shortly be published in the 'Journal of Genetics,' on the inheritance of green, variegated, and yellow leaves in Primula. The variegated plants consist of a mosaic of two kinds of cells, respectively like those of the pure green and pure yellow-leaved plants. The characters of the chloroplasts, on which greenness and yellowness depend, have been found to

be inherited through the egg-cell only, the male gamete playing no part in determining the nature of the offspring in respect of these characters.

The experiments of Mr. R. P. Gregory and Miss Gairdner on the inheritance of variegation and other characters in *Tropæolum* have been continued. It is hoped that sufficient data will have been gained by the end of the present season to permit of the publication of an account of this work. Present results indicate that in *Tropæolum* variegation is inherited in the usual way from both the father and the mother, and is a Mendelian recessive character. Other characters in *Tropæolum* which are being studied are those of colour and habit (dwarf or trailing).

The experiments on the gynandrous variety of the Wallflower and its relation to the normal type are nearing completion, and it is hoped that an account of them will be published next year.

The Committee ask for reappointment with a grant of 45*l*. The expenses of these experiments involve an annual outlay of about 110*l*. to 120*l*. By far the largest item in this expenditure is the cost of labour, which has increased during the last few years with the general rise in wages which has taken place. Other important items are those of the rent of the garden and the cost of heating the *Primula* house. During the present year Miss Saunders and Mr. Gregory jointly receive a grant from the Royal Society of 60*l*. in aid of the cost of this work.

Breeding Experiments with Œnotheras.—Report of the Committee, consisting of Professor W. BATESON *(Chairman)*, Professor F. KEEBLE *(Secretary), and* Mr. R. P. GREGORY, *appointed to carry out the Experiments.*

THE Committee have received the following Report from Dr. R. R. Gates on the experiments which he has made:—

'The grant of 20*l*. made by the British Association for *Œnothera*-breeding has been applied to the expenses of these experiments during the last year. In the season of 1913 about 10,000 plants were grown, representing a great many races and hybrids of *Œnothera*. The plants were grown at Rothamsted on a two-acre plot set apart for the purpose. They developed very successfully, nearly every individual reaching maturity. The largest series of hybrids were the F_3 from *Œ. grandiflora, Œ. rubricalyx* and its reciprocal, and the F_3 of crosses between *Œ. grandiflora* and *Œ. Lamarckiana*. The F_3 generation of the former cross confirms and extends the results of the F_1 and F_2 generations already published in 'Zeitschr. f. Abst. u. Vererb.,' vol. xi. They show in particular that both blending and alternative inheritance of characters occur. Some of the plants, which have been examined cytologically in conjunction with Miss Nesta Thomas, further emphasise the fact that mutation and hybridisation in *Œnothera* are separate processes, both of which may go on together. Some of these results will be incorporated in a book now in preparation.'

The Renting of Cinchona Botanic Station in Jamaica.—Report of the Committee, consisting of Professor F. O. BOWER (*Chairman*), Professor R. H. YAPP (*Secretary*), Professors R. BULLER, F. W. OLIVER, *and* F. E. WEISS.

THE Committee has met twice. The negotiations with the Jamaican Government are progressing favourably, the Committee having been assisted by the advice of Sir David Prain. There is every prospect of the house and buildings being let to the Committee on an annual tenancy to commence from October 1, 1914, at a rent of 25*l*. There has, however, been considerable delay, partly owing to the long posts, partly to the progress of papers through official channels.

As no agreement has yet been signed the grant of 25*l*. has not been drawn. But in view of the prospect of negotiations being completed on the terms above stated, the Committee ask that they may be reappointed, and that the grant of 25*l*. be carried over to the ensuing year as an unexpended balance.

Mental and Physical Factors involved in Education.—Report of the Committee, consisting of Dr. C. S. MYERS (*Chairman*), Professor J. A. GREEN (*Secretary*), Professor J. ADAMS, Dr. G. A. AUDEN, Sir EDWARD BRABROOK, Dr. W. BROWN, Professor E. P. CULVERWELL, Mr. G. F. DANIELL, Miss B. FOXLEY, Professor R. A. GREGORY, Dr. C. W. KIMMINS, Professor McDOUGALL, Drs. T. P. NUNN, W. H. R. RIVERS, *and* F. C. SHRUBSALL, Mr. H. BOMPAS SMITH, Professor C. SPEARMAN, Mr. A. E. TWENTYMAN, *and* Dr. F. WARNER, *appointed to inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.*

THE Committee has to report the retirement of its Chairman, Professor J. J. Findlay, and the election of Dr. C. S. Myers in his place.

They have been engaged in collating the data which was provisionally reported upon at Birmingham, and hope to present the results in a definite form for the Manchester Meeting in 1915. The Committee asks to be reappointed, and applies for a grant of 30*l*., to include the unexpended balance from this year's grant.

Influence of School-books upon Eyesight.—Interim Report of the Committee, consisting of Dr. G. A. AUDEN (*Chairman*), Mr. G. F. DANIELL (*Secretary*), Mr. C. H. BOTHAMLEY, Mr. W. D. EGGAR, Professor R. A. GREGORY, Mr. N. BISHOP HARMAN, Mr. J. L. HOLLAND, *and* Mr. W. T. H. WALSH.

IN previous reports (1912 and 1913) reference was made to the injurious effect of shiny paper, in particular to the interference with binocular

vision which may result from excess of specular reflection. The Committee is investigating the proportion of specular to diffusive reflection in the case of books and writing-papers used in schools, and has received valuable assistance from Mr. A. P. Trotter, who has devised a gloss-tester. The Committee desires to continue this investigation in the hope of arriving at an objective standard the adoption of which would prevent injury to eyesight through the use of glossy paper, and therefore asks to be reappointed with a grant of 5*l.* in addition to the unexpended balance of last year's grant.

Museums.—Report of the Committee, consisting of Professor J. A. Green *(Chairman)*, Mr. H. Bolton *and* Dr. J. A. Clubb *(Secretaries)*, Dr. Bather, Mr. E. Gray, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood *and* P. Newberry, Sir Richard Temple, Mr. H. H. Thomas, Professor F. E. Weiss, *and* Mrs. J. White, *appointed to examine the Character, Work, and Maintenance of Museums.*

The Committee report that a detailed schedule of inquiry upon Museums has been drawn up and presented to the House of Lords by Lord Sudeley. It is hoped that the schedule will be issued by the Board of Education, and that the information obtained will be available for the purposes of the Committee. Opinions and reports have been obtained upon various sections of museum work and their relation to various divisions of Education. Other inquiries of a similar nature are also being made. Offers of assistance have been received from the American Association of Museums. Two members of the Committee will examine overseas museums during their journey to and from Australia and report.

A deputation will report upon the educational work of Museums in France.

The following questions are receiving special consideration:—

The requirements of (1) students; (2) school children; (3) general visitors to museums.

The Committee ask to be reappointed with a grant of 30*l.*, including the balance, 7*l.* 9*s.* 2*d.*, of last year's grant, now in hand.

On Salts Coloured by Cathode Rays.

By Professor E. GOLDSTEIN.

[Ordered, on behalf of the General Committee, to be printed *in extenso.*]

PERHAPS a part of the phenomena which I am about to discuss is already familiar to you all. I shall not bring forward many hypotheses. So you will perhaps ask why I should speak at all. And, in fact, apart from reference to certain facts not published hitherto, my intention is mainly to invite the interest of men younger and abler than myself in a class of phenomena which seem to constitute a new condition of matter, but on which very few have yet worked.

If cathode rays fall on certain salts—for example, common salt, or chloride of potassium, or potassium bromide—vivid colours are produced immediately on these salts.[1] Thus common salt becomes yellow-brown (like amber), potassium chloride turns into a beautiful violet, potassium bromide becomes a deep blue colour quite like copper sulphate. Here you see a specimen of common salt transformed in this way on the surface of the single crystals into a yellow-brown substance. I show also sodium fluoride, which takes a fine rosy colour.

The colours so acquired in a very small fraction of a second may be preserved for a long time, even for many years, if the coloured substances are kept in the dark and at low temperatures. But in the daylight, and also under heat, the colours will gradually disappear till the original white condition is reached again.

The colours of different salts are sensitive to heating in a very different degree. I could show you the yellow sodium chloride, prepared some months ago in Europe, but I cannot show you here the violet KCl and the blue KBr, because these colours, even in the dark, do not stand the heat of the Equator. The same salt, if dissolved, may keep very different colours, according to the medium in which it has been dissolved, even when the pure medium itself cannot be coloured at all by cathode rays. I am speaking of *solid solutions*, produced by fusing a small quantity—for instance, of common salt or of certain other alkali salts—together with a great mass of a salt which remains itself colourless in the cathode rays, as, for example, the pure potassium sulphate. Lithium chloride acquires a bright yellow colour in the cathode rays; but if dissolved in potassium sulphate a lilac hue is produced, as you may see in this specimen. Likewise the pure carbonate of potassium acquires a reddish tint, but after dissolving it in the potassium sulphate it becomes a vivid *green* in the cathode rays, as you see here.

Very small admixtures are sufficient to produce intense colours. So $\frac{1}{25000}$ of carbonate will produce the green colour in the potassium

[1] E. Goldstein, *Wiedem. Ann.* **54,** 371 ; **60,** 491 ; *Phys. Zeitschr.* **3,** 149 ; *Sitzungsber. Berl. Akad. d. Wiss.* 1901, 222.

sulphate; even $\frac{1}{1000000}$ gives a marked colour, and an amount of certain admixtures, which I estimated as $\frac{1}{1000000}$ only, may produce a slight but quite perceptible colouration in some salts. So if you work with potassium sulphate which you obtain from chemical factories guaranteed as chemically pure, you may observe a set of different colours in these preparations under the cathode rays, by which you will detect the nature of the different small admixtures which adhere to the pretended pure preparations of the different factories. In this way a new analytical proof, much more sensitive than the ordinary chemical methods, is obtained, and impurities may be detected even when a certain specimen of salt contains more than a single impurity, because the colours produced by different admixtures generally disappear with different speed in the daylight or under rise of temperature. For instance, the ordinary potassium sulphate turns to a dark gray with a slight greenish tint at first. After a short while the very sensitive gray will disappear, simply under the ordinary temperature of the laboratory room, and a vivid green comes out. The gray hue indicates a very small amount of sodium chloride, $\frac{1}{100000}$ or so, and the remaining green indicates the admixture of a carbonate. Here are some preparations of potassium sulphate each containing a single small admixture (K_2CO_3, Li_2CO_3, LiCl, KCl, KBr). You will notice how different are the colours of the originally white substance, varying from green to bluish gray, ash-gray, grayish blue, and violet.

By fractional crystallisation one may finally get a really pure preparation of potassium sulphate, which is no longer coloured by cathode rays (or only in a very slight degree, indicating minimal traces of sodium chloride). But there are other preparations which, so far as I know, cannot be acquired in pure condition by any means, not even by fractional crystallisation. I never came across a pure sodium sulphate—the purity exists only on the manufacturers' labels. Even the best preparations of this salt contain an amount of sodium carbonate which up to the present cannot be separated from it, not even by frequent fractional crystallisation. The colour produced by the small admixture, which always remains, is a very marked ash-gray. By an intentional further addition of sodium carbonate the colour becomes nearly black.

The question arises: What may be the cause of these colourations in pure salts and also in solid solutions of them? Shortly after the colours of the alkali salts had been discovered, an explanation was given[2], according to which the phenomenon mainly consists in a chemical reduction. For instance, in the case of potassium chloride the chlorine would be set free, while the remaining potassium is dissolved in the unaltered main quantity of the salt, colouring it at the same time. And it seemed a convincing proof for this theory when Giesel[3] and also Kreutz, simply by heating rock salt in the vapours of sodium or of potassium, produced colours in this rock salt quite similar to those produced by cathode rays. It seemed that

[2] E. Wiedemann and G. C. Schmidt, *Wied. Ann.* **54**, 618.
[3] F. Giesel, *Ber. D. Chem. Ges.* **30**, 156.

the problem was settled finally. However, it was soon discovered that the coloured Giesel salts, although they look to the eye quite like the cathode-ray salts, in all other respects behave quite differently. For instance:—

(1) The cathode-ray salts, as I mentioned before, are very sensitive to daylight: after an exposure to diffuse daylight of a few minutes—or in some salts even of several seconds only—the colouration diminishes, whilst the Giesel salts remain unaltered even when they are kept in full sunshine for days or even weeks.

(2) The cathode-ray salts, if dissolved in distilled water, show absolute neutral reaction; the Giesel salts are strongly alkaline.

(3) The cathode-ray salts give very marked photoelectric effects (as Elster and Geitel [4] observed); the Giesel salts are quite ineffective.

(4) Under certain circumstances, which will be mentioned further on, the cathode-ray salts may emit a phosphorescent light, the Giesel salts none at all. Therefore the question arose again, whether there is not a marked internal difference between the cathode-ray salts and the Giesel salts, and what is the nature of the latter?

I have succeeded in settling this question, having produced salts *by cathode rays*, the behaviour of which is in every respect *absolutely identical with the Giesel salts*. You may produce such substances if you allow the cathode rays to fall on the original salts not for a short moment only, but for a somewhat prolonged time, *until the salts are strongly heated*. Produced in this way the salts will keep colours; but the substances coloured in this way are *not* sensitive to light; they show no photoelectric effect; they give *strong alkaline* reaction, and they are not suited for phosphorescence—all like the Giesel salts. It is quite sure, and you may test it also directly by spectroscopic proof, that in this case, if for instance you have worked on sodium chloride, *the chlorine is set free*. Then of course an amount of free sodium is left, which dissolves itself in a deeper layer of unaltered sodium chloride, to which the cathode rays could not penetrate. I call these non-sensitive colours *the after-colours of the second* class, while the ordinary sensitive after-colours, produced in a short time on cool salts, are called after-colours of the first class.

Now, if the after-colours of the second class are identical with the Giesel salts, then, of course, the very different substances of the first class cannot be also identical with the Giesel salts. Therefore the question arises anew what is the nature of the first-class after-colours?

One observes with regard to solid solutions that the first-class colours depend not only upon the *metal* contained in the small admixture, but they vary greatly, for instance, in the case of the admixture consisting of potassium chloride or bromide or iodide. This indicates that the metals alone do not cause the after-colours. It becomes much more clear when we expose some ammonium salts to the cathode rays. (The ammonium salts are cooled by liquid air in the discharge-tube to prevent their evaporation.) Then you get strongly marked after-colours likewise; for instance, ammonium chloride becomes yellow-greenish, the bromide becomes yellow-brown, the iodide becomes brown, and the

[4] J. Elster and H. Geitel, *Wied. Ann.* **59**, 487.

fluoride a deep blue. In the daylight these colours are gradually destroyed, quite like other after-colours of the first class. The colours themselves—yellow-greenish for the chloride, yellow-brown for the bromide, and so on—induce us to presume that the after-colours in this case are produced by the haloids, and not by the hypothetical ammonium radical. This presumption becomes a strong conviction when we observe that also a great number of organic preparations which contain no metal at all (and not any metal-like radical) acquire marked after-colours of the first class in the cathode rays also. (The part of the discharge-tube which contains the organic substances is cooled by liquid air.)

Then you may observe that solid acetic acid ($C_2H_4O_2$) remains quite colourless in the cathode rays; but if you substitute a hydrogen atom by chlorine, the substance thus produced (the monochloro-acetic acid) acquires a marked yellow-green after-colour. If you introduce an atom of bromine instead of chlorine, you get $C_2H_3BrO_2$ and the after-colour is of a marked yellow. Bromoform ($CHBr_3$) turns into the colour of loam, and chloral (C_2HCl_3O) becomes a deep yellow. In this way we see that not only salts, but likewise substituted acids, substituted hydrocarbons, and substituted aldehydes acquire after-colours if they contain any haloid.

Now, it seems highly improbable that in the case of alkali salts the electro-positive component is absorbed only (producing the after-colour), and that, on the other hand, in the ammonium salts and in the organic substances the electro-negative component is efficient only. The most probable inference is that in each case *both* components remain and that both are efficient, but that under the same conditions the haloids produce a slighter colour than the metals, so that in the case of the salts the haloid colour is overwhelmed by the metal colour.

Therefore we are compelled to suppose that we have not to deal with a decomposition in the ordinary form, by which the different components are finally separated from each other and at least one of them is set entirely free, but that the components detained by absorption remain at a quite short distance from each other, so that they may easily meet again. I realise that—for instance, in the case of sodium chloride—at every point of the coloured layer there is an atom (or perhaps a molecule) of chlorine and an atom (or a molecule) of sodium; but they cannot combine, because they are fixed by absorption and distended from each other by the absorptive power, which in this case surpasses the chemical affinity. But the absorptive power may be weakened by heating and the chemical affinity or the amplitude of the molecular vibrations may be strengthened by the energy of daylight.

If we grant these assumptions, it is immediately evident why the reaction of all dissolved colour substances of the first class is a neutral one, for the two components may combine again and re-establish the original substance. The other special qualities of the first-class colours, and especially their differences from the Giesel salts, which contain the electropositive component only, may be deduced likewise from this retention of both components and their opportunity of meeting each other again when the absorptive power is

weakened or the chemical affinity is strengthened. Now, the two components in the coloured substances being distended in some degree, I propose for this special condition of matter the name of *distension*. If we accept this, have we created a new name only, or does matter in this condition really show new qualities? It seems to me that we have to deal with a peculiar condition of matter, which deserves a more elaborate study than it has met till now. I will not enter again into some special qualities, which have already been mentioned—the photoelectric effect and so on—but I should like to point out that matter in the distension state shows a strongly strengthened absorption of light.

We noticed with regard to ammonium chloride the yellow-greenish after-colour of the chlorine. Now, cathode rays, as used in these experiments, will not penetrate any deeper than one-hundredth of a millimetre into the salt. In such a thin layer even pure liquefied chlorine would not show any perceptible colour. But besides this it must be noticed that we observe this after-colour at the temperature of liquid air, and that chlorine at this temperature, as Dewar and Moissan observed, is snow-white, even in thick layers. In a similar degree the brown colour of bromine is weakened at low temperatures. Now, if nevertheless we observe at this very low temperature the marked characteristic colours of chlorine and bromine, we must conclude that the absorptive power of these substances has become a multiple of its ordinary value. One may observe this strengthening of the absorptive power directly in the pure sulphur. Sulphur likewise turns into a snow-white substance if cooled by liquid air. But when the cathode rays fall on the white sulphur it takes immediately a yellow-reddish colour. It is a real after-colour, because at constant low temperature the colour is destroyed by daylight.

Now, since the strengthening of light-absorption occurs in this elementary substance, it becomes evident that the cause cannot be any chemical process, but only a physical allotropy. The special character of this allotropy (which may be connected with an absorption of electrons) will not be entered on in a discussion here. Probably we have to deal with a polymerisation, so that, for instance, the yellow-reddish sulphur would be analogous to polymerised oxygen—to ozone.

I have mentioned already that the first-class after-colours are gradually destroyed by incident daylight. A peculiar phenomenon is connected with this destruction of colour. I found that after the daylight had fallen on the coloured substances, even for the shortest time, most of them showed a marked phosphorescence of long duration. I have observed this phosphorescence even in substances which had been coloured twelve years ago and had been kept in the dark since that time. The diffused dim light of a gloomy November day, when falling through a window on the coloured substance for one or two seconds only, is sufficient for the production of this phosphorescence in a marked degree. If you allow the daylight to fall several times on the same spot, then the colour is weakened at this spot, and we come to the presumption that the loss of colouration is generally

attended by the emission of phosphorescent light. This is in accordance with the experience of Wiedemann and Schmidt that if the destruction of the colour is produced by heating, likewise a phosphorescent light is produced, which in this case is strong but of a short duration, corresponding to the quick destruction of the after-colours by strong heating.

If the salts, after having been coloured in the condition of a fine powder and then having been put between two glass plates (in order to obtain a plane surface), are placed in a photographic camera instead of the photographic plate, you may get a fine phosphorescent picture of a landscape or of architecture after a very short exposure.

Time does not allow me to mention in detail several other peculiarities which are shown by matter in the distension state. In one direction only I may be allowed to make some remarks.

The first-class after-colours may be produced not only by cathode rays but also by the β rays of radioactive substances, as you probably know. But they may also be produced by *ultra-violet light*, for instance, by ultra-violet spark light, even when a quartz plate is interposed between the spark and the salt. More than thirty years ago I brought forward a hypothesis, according to which in every point where cathode rays strike a solid body a thin layer of ultra-violet light-radiating molecules is produced in the gas, to which ultra-violet light of very short wave-lengths, for instance, the phosphorescence of the glass walls in the cathode rays, is due. But I came further to the assumption that nearly all effects which are commonly ascribed to special qualities of the cathode rays, and likewise of β rays and x rays, are mere effects of the ultra-violet light which is produced by the stopping of these rays. I have been guided by this assumption during many years, and have very often been aided by it in foreseeing new phenomena. For instance, in this way I was induced to expect that the after-colours would be produced not only by cathode rays but also by the ordinary ultra-violet light; further I could guess that also the x rays would produce after-colours (which in this case have been observed by Holzknecht), and in recent times I could foresee that solid aromatic substances (the benzene derivatives) in the ultra-violet light must change their spectra of ordinary phosphorescence, composed of broad bands, and turn to peculiar spectra composed of narrow stripes, the wave-lengths of which are characteristic of the single aromatic substances.[5] So I believe also that the after-colours are produced not directly by the cathode rays or by β rays, but by the aforesaid ultra-violet light which is connected with the stopping of the other rays.

In this way the after-colours enter at once into a great class of phenomena known as *reversible effects of light*. You know that certain effects of the visible spectral rays are destroyed by rays of longer wave-lengths, by the infra-red rays. And the analogy to this phenomenon is in my opinion the destruction of the after-colours: they are produced by the ultra-violet light of the stopped cathode rays and are annihilated by the longer visible wave-lengths of daylight. In this way you may likewise understand, for instance, that the coloured

[5] E. Goldstein, *Verhandl. d. D. Physik. Ges.* **12**.

spots, produced by x rays on the luminescent screens after long exposure, may be destroyed again by exposure of the screens to daylight. You may also explain the peculiar medical observation that therapeutic radium effects in parts of the human body not covered, specially in the face, are often not of long duration—for the face is exposed to the counteracting visible rays of daylight.

We notice here a connection of our subject with a department of great practical importance. For all therapeutic effects of x rays, radium rays, and mesothorium rays would, according to this view, be effects only of ultra-violet light produced by the stopping of these rays in the human body, and the special character of the radium- and mesothorium- and x-ray treatment would consist mainly in the carriage into the interior of the body, by the rays, of the ultra-violet light, which is not confined to the surface of the body, but is produced at every place where any of the entering rays are stopped. You may notice further that this view of the medical ray-effects presents a heuristic method for the treatment itself, which up to the present followed quite fortuitous and merely empirical paths. For it may be hoped that treatment by radioactive substances will be useful in every disease in which ultra-violet light has been proved to be efficient in some degree; you will avoid such treatment in the well-known cases in which light of short wave-lengths is noxious, and you may be justified in substituting an ultra-violet light treatment where radium or mesothorium is not obtainable. At the same time it becomes evident why the treatment of certain diseases by the β rays has effects very similar to those produced by *fulguration*—that is, by the light of very strong sparks: the efficient agent is in both cases the ultra-violet light.

But it cannot be a physicist's task to enter too far in medical questions: it was only my intention to show how interesting are some of the problems which are connected with the salts coloured by cathode rays.

The Problem of the Visual Requirements of the Sailor and the Railway Employee. By JAMES W. BARRETT, *C.M.G., M.D., M.S., F.R.C.S. Eng.*

[Ordered, on behalf of the General Committee, to be printed *in extenso.*]

THE discussions which have taken place on this subject are apparently interminable. They have for the most part resolved themselves into discussions amongst oculists and communications made by deputation or otherwise to the Board of Trade presenting their point of view.

The Board of Trade, whilst it has collected a certain amount of valuable information, has not materially modified its methods, and apparently does not propose to do so. As its authority weighs heavily in the Dominions, which are as a rule not consulted by it before it takes action, various anomalies make their appearance. I venture therefore to bring before this meeting of the Physiological Section of the British Association a summary of the present position.

Until recently the standard adopted by the Board of Trade was normal colour vision as tested by coloured wools and a form vision equal to 6/12 partly with both eyes open. In other words, the theoretical objective was normal colour vision, and form vision of such a standard that one eye might be totally blind and the other possess somewhat less than half vision. The Board, however, appointed an expert committee in 1910, which took evidence and made a number of recommendations. This committee sat for two years, and in its report recommended that the form vision required should be 6/6 in one eye and 6/12 in the other, and that colour vision should be tested by wools and by coloured lanterns. It did not, however, definitely recommend that the eyes of those who enter dangerous services should be subjected to a complete ophthalmological examination when the boy first goes to sea. Apparently such changes would have required fresh legislation.

Since this report, however, the Board of Trade has again altered its requirements, and now requires the candidate to read 6/9 partly and 6/6 partly with both eyes open, which means, simply, that the old standard has been reverted to as regards form vision, except that the minimum has been raised from 6/12 partly to 6/9 partly. During the course of its long inquiry the expert committee apparently did not consult those in the Dominions who were dealing with the matter, with the exception of the examination of two witnesses, nor did they apparently seek to make any careful reference to the various accidents which have taken place by sea and land and can be attributed to defective vision.

Clause 13 of the Report of the Departmental Committee on Sight Tests states:—'Sir Walter Howell informed us that the Board of Trade were not aware of any casualty which could be traced to defective vision. He explained that the Board could raise any question they pleased on an official inquiry into a marine casualty; that the smallest question as to the colour vision of any officer concerned would be probed to the bottom; that if there were any question of confusion the men concerned would be re-tested; but that such a question had not been raised in a single instance. We have examined a large number of the Reports of Board of Trade inquiries, and the result of our examinations has confirmed the view that no official evidence exists of casualties due to this cause. We have examined eight master mariners of long experience, none of whom knew of any case in which a casualty had arisen from defective vision.'

Clause 14.—'At our request the Liverpool Steamship Owners' Association ascertained that, of its members, the owners of 857 steam vessels, of the aggregate tonnage of 3,776,695 tons, knew of no instances in which mistakes due to defective form or colour vision had been made in the reading of lights at sea, and of no instance of difficulty of reading signals; while the owners of 59 steam vessels of 192,494 tons knew of some few instances in which a man's sight had been or had been alleged to have been defective, but of no casualty resulting therefrom.'

Clause 15.—'The Secretary of the Joint Arbitration Committee at Grimsby, which investigates the circumstances of a large number of collisions every year, has never known of a collision caused through

the mistaking of the colour of a light. The Manager of the Hull Steam Trawlers' Mutual Insurance and Protection Co., Ltd., who in 12 years has had to deal with an average of 100 collisions a year, knows of only four cases in which any question of defective vision has arisen. Two of these cases were in elderly men, and in the other two the witness considered the danger was caused by excessive smoking.'

Clause 17.—'The Board of Trade casualty returns, which include collisions to foreign ships on or near the coast of the United Kingdom and of British Possessions, show no case in which a sea casualty has been attributed to the defective vision either of an officer or a look-out man; but they show that since the adoption of the 1894 sight tests there have been reported on the average each year 100 collisions attributed to bad look-out and 429 strandings attributed to causes connected with navigation and seamanship. The strandings resulting from bad look-out are not shown separately. From these returns it is not possible to arrive at any reliable estimate of the total number that might have been occasioned by the defective vision of the officer in charge or of the man on the look-out. Further, the returns, as they do not distinguish the vessels commanded by officers who have passed the 1894 sight test, afford only a general basis of determining how far the existing system has been successful in eliminating dangerously defective men; but they do show that amongst the vessels registered in the United Kingdom the total number of collisions attributable to bad look-out and of strandings attributable to all causes relating to navigation and seamanship is less than 500 a year. The Board of Trade has no record of the actual number of voyages made by British vessels, but on a rough estimate that number cannot be less than 300,000 a year.'

Clause 18.—'There appears to be no evidence showing conclusively that defective vision has caused any appreciable number of accidents at sea, although we do not think that it necessarily follows from this that the present method, even where it has been employed, has been successful in excluding all dangerous persons from the Mercantile Marine, or that no accidents have been caused in this way, since it has not been the practice, in conducting inquiries into the causes of casualties, to test the vision of persons implicated. We think it regrettable that effect has not been given to the recommendation as to the testing of witnesses contained in the report of the committee of the Royal Society in 1894, and we desire to repeat that recommendation—that in case of judicial inquiries as to collisions or accidents witnesses giving evidence as to the nature or position of coloured signals and lights should be themselves tested for colour and form vision.'

Sir Norman Hill, who signed the Minority Report, states that 'in the absence of all evidence of any single casualty resulting from defective form vision I am opposed to the retention of the new standard under which 10 per cent. of the candidates who have for many years proved their competency would have been excluded from the service.' Mr. Nettleship, however, one of the members, since the publication of the Report, made a collection of the cases in which disaster at sea or land seemed to be actually or potentially due to these causes, and was in communication with the writer in regard to the details of a number

of other cases at the time of his death. In that work Mr. Nettleship makes the following pertinent observation (p. 3):—'For reasons such as the above, defects in sight are regarded by those who have to inquire into accidents as of such little importance that in the official investigations the question of defects of sight in the men who are on look-out or corresponding duty is scarcely ever raised. Naturally, therefore, no accidents are discovered to have had visual defects for their cause. Continuing to reason in a circle, the conclusion is that defects of sight do not cause accidents! It would be ludicrous if the matter were not so grave that though precautions of greater or less efficacy are taken to exclude men with conspicuous defects of sight from entering the sea or railroad services because such defects are admittedly dangerous, yet, when the accident happens, no trouble is taken to find out whether the man responsible for it has efficient sight or not. Every possible cause for the casualty is sought out, but the possibility that his vision either was defective when he entered the service or has become so since is never even considered.'

Yet in spite of the foregoing the fact remains that Dr. Orr and I reported in the *Lancet*, October 29, 1904, the account of the wreck of the *Australia* and the previous grounding of the *Indraghiri* by a pilot whose form vision was very defective. In spite of this Report, the statements of Sir Walter Howell and Sir Norman Hill appear in the Expert Committee's Report. I propose now to refer to the methods adopted in the Victorian Railways, the Victorian Pilot Service, and the Union S.S. Co. of New Zealand. The history of vision-testing in the Victorian Railways is too lengthy for detailed reference. The number of candidates who have to be dealt with is very large, and the Department has adopted a rough-and-ready plan with which I am not in complete sympathy, but which undoubtedly eliminates the majority of the defective cases. Colour vision is tested by the lantern and form vision by Snellin's types. For those entering the service the vision required is 6/6 in each eye and 6/6 in both together. The pupil is then dilated with homatropine and the vision is again tested. It must now not be less than 6/12 in each eye or 6/12 in both together. Once the applicants are admitted to the service they are re-tested without the use of homatropine, and must possess 6/12 vision in each eye and 6/9 in both together.

I propose now to indicate the steps that have been taken by the Marine Board of Victoria to provide for the thorough examination of the vision of pilots who enter their service, and for their re-examination since the disaster of 1904. I also quote Clauses 100, 102, 104 and 105 of the regulations which provide for the contingencies to which Mr. Nettleship referred.

Victorian Pilot Regulations.

Pilots must be examined prior to admission to the service, and their vision must be as follows:—

1. Vision to be 6/6 in each eye without glasses.
2. The total error of refraction not to exceed 1 d, and of this

astigmatism not to exceed ·5 d. This estimate to be made by retinoscopy with the eye under the influence of a mydriatic.

3. The pupillary reflex to be normal, the fundus to be free from disease, visual fields normal, and balance of colour muscles to be normal. Candidate to possess binocular vision.

4. Colour vision to be normal as tested by coloured wools and coloured discs.

If persons possessing these qualifications are admitted, on re-examination the standard required is:—

1. The same as in the case of an applicant for a licence, except that after admission into the service deterioration of vision will be allowed, provided that the vision is not less than 6/9 fully and 6/6 partly in each eye.

2. There must be no evidence of any morbid or other condition in either eye which would render it probable that the vision would deteriorate before the next periodical examination.

Clause 100 provides that 'every pilot until he arrives at the full age of sixty years, whether licensed before or after the coming into force of these regulations, shall at intervals of not more than twelve calendar months, and in the case of a pilot who under the regulations does not necessarily retire at the age of sixty years, after he attains that age, at intervals of not more than six calendar months, have his eyes examined and vision tested, and pass as satisfying the prescribed standard by an expert oculist to be approved by the Marine Board.'

Clause 102 provides:—'If, on the occasion of any examination or testing of a pilot or of his eyesight or vision (whether biennial, sixth monthly, or casual) any physical, mental, or visual defect is discovered which in the opinion of the medical examiner or expert oculist, as the case may be, does not immediately, but may within a variable time, render the pilot unfit for service, such pilot shall submit himself for re-examination within such lesser intervals than those hereinbefore prescribed as the examiner or oculist, as the case may be, may certify to be necessary, any longer interval hereinbefore limited to the contrary notwithstanding.'

Clause 104 provides:—'In the event of any casualty or accident occurring to or in connexion with any vessel or incidental to the navigation thereof, which in the opinion of the Marine Board may be due to or of which in its opinion one of the contributing causes may have been some defect in health or vision of the pilot in charge, such pilot shall if required by the Board forthwith submit himself and be examined by a medical practitioner or expert oculist to be nominated by the Board, or by both, as the Board may direct, and until such practitioner or oculist or both, as the case may be, shall certify that such pilot is fit physically and mentally or visually, and such certificate be lodged with the Secretary to the Board, such pilot shall not follow his calling.'

Clause 105:—'If any pilot be absent from duty on account of illness, and such absence shall extend beyond twenty-eight days, or in case of illness of any duration, if the Marine Board think it advisable, or when from any other cause any pilot has been absent from duty and

such absence shall have extended for six calendar months or upwards, such pilot shall not return to duty unless and until, as regards his condition physical and mental, a medical practitioner and, as regards his vision and eyesight, an expert oculist, to be in both cases nominated by the Marine Board, have respectively certified to the Board that such pilot is in a fit condition physically, mentally, and visually to perform his duties as a pilot.'

The annual examination of the pilots has probably averted disaster, as one pilot was retired with high blood-pressure and retinal hemorrhages detected in the course of periodical examination.

The Union Steamship Company of New Zealand adopts a like standard for those who enter its service, and provides for periodical testing of form vision.

What standard of form and colour vision is necessary for safe navigation or railway service?

So far as colour vision is concerned the results of the ordinary tests with wools and lanterns seem to coincide with the quantitative measurements made by Sir William Abney, and I have never seen any practical difficulty in detecting a dangerous degree of colour defect by the combination of these means.

With regard to form vision, however, the matter is not nearly so simple. Two questions arise: What standard of form vision shall be required? and, Are two eyes necessary? Some time ago, in the *Ophthalmic Review*, Mr. Fergus gave an account of his own experience in motor navigation with defective vision. Apart from theoretical disquisition which I was unable to follow, he stated correctly enough that lowered form vision means for the most part a loss of detail. A house is still seen as a house at a distance when the form vision is lowered, and a ship is still seen as a ship in like circumstances. I, however, set to work to make myself artificially myopic with bi-convex glasses, and to reduce my form vision to different degrees in order to repeat his experience. In passing, however, it should never be forgotten that the standards given by Snellin's types are at best approximate. They depend on the illumination of the types, on the contrast between the letters and the background, on the illumination of the room, and the size of the pupil. They nearly always give better results in daylight than by artificial illumination. At best they have approximate significance.

Rendering my eyes artificially myopic in this way, I reduced my vision to 6/9 partly and 6/12, and found, as Mr. Fergus said, that houses, men, dogs, and objects of various kinds were still recognised as such, but certain details could not be detected. For example, a man and a dog at five hundred yards' distance were seen as one mass; a flag on a flagpole at a distance of a mile was indefinite, so that one could not tell which way the wind was blowing. Outside Dunedin Harbour I mistook a ship on the rocks for the rocks themselves. By bright ordinary daylight I should have experienced little or no difficulty in navigating. Furthermore, in a long motor run there was not the least difficulty in seeing details on the road, and there would have been no difficulty in steering the motor. At evening, however, and at night,

the matter was entirely different, and with this reduced vision motor driving would have been full of difficulty and danger by reason of the reduction of the range of vision. When, however, I lowered the vision to 6/18 partly navigation and motor driving would have been dangerous by night or day.

The experimental evidence obtained by the Expert Committee at Shoeburyness was to the effect that vision of less than 6/12 seriously affects colour perception, and that consequently 6/12 represents the minimum of vision compatible with safety. This accords with my own personal experience, with the reservation that anyone who possesses 6/6 vision will be a much safer navigator, other things being equal, than anyone who possesses 6/12 vision.

Mr. Fergus seems to draw a distinction between myopia and hyperopia, but when I have rendered my vision defective by rendering my eyes hyperopic—that is, by the wearing of concave spectacles—I have been unable to detect any practical difference in the result. In both cases one makes many failures when one's colour vision is tested by the lantern. When the aperture is small and the light a little dim, no colour can be seen at all, probably for the reason that Sir William Abney instances.

In Sir William Abney's work, dated 1913, 'Researches in Colour Vision' (p. 409), reference to similar experimental work is made. The writer, a few years ago, when considering other causes than those of deficient colour sensation which might prevent the recognition of colour, came to the conclusion that the optical condition of the eye might be of such a nature that small discs of coloured light might be taken as colourless or not seen at all. To confirm or disprove his diagnosis he made his eye myopic and observed a ship's light from the sea-coast and also known stars, and found that with about half normal vision the ship's light at two miles was sometimes invisible or colourless, and that only stars above the fourth or fifth magnitude could make any impression on the retina.

Conclusion.

There is abundant evidence to show that a number of disasters by land and sea are attributable to defective vision. There is also good reason for thinking that a larger number of accidents have occurred which have not been reported, and, as Mr. Nettleship says, they never will be reported under existing conditions. It is clear that, so long as the present mode of lighting ships and the present method of using railway signals are continued, form vision below 6/12 is dangerous as regards its effect on colour perception, and is dangerous by reason of the limitation of the range of vision in dull light, and I am of opinion that for the purposes of safety the minimum visual requirements should be 6/9 in one eye and 6/18 in the other. A hypermetropia of two dioptres with astigmatism not exceeding ·75 D might be permitted. The colour vision should be normal and tested both with wools and lights, and there should be no ocular disease. To satisfy these requirements it is necessary that all those who go to sea or enter the railway service to earn a livelihood should be examined at

the outset of their career, since one complete ophthalmological examination at that period of life will enable the future vision of the examinee to be predicted with tolerable certainty.

It will be seen that the method adopted by the Victorian Railways would eliminate those who have a high degree of hypermetropia; but it may admit those suffering from choroiditis with contracted fields, from glaucoma, and, in fact, any eye disease which is not obvious and which has no lowered central form vision.

Stress need hardly be laid on the injustice perpetrated in allowing anyone to enter a seafaring life, to spend some years in acquiring proficiency, and then subject him to a visual examination when he makes his appearance for his first professional examination. The sensible course is obviously to insist on a complete examination when the boy first goes to sea.

Dry-Farming Investigations in the United States. *By* LYMAN J. BRIGGS, M.S., Ph.D.

[PLATE V.]

(*Ordered, on behalf of the General Committee, to be printed in extenso.*)

THE term 'dry-farming' is now generally applied to agricultural practice in regions where rainfall is the primary limiting factor in crop production. The determination of the tillage methods which are most efficient in the storage and conservation of moisture, and the development of varieties which are especially suited to dry-land conditions, are economic problems worthy of the best efforts of the agronomist. The most efficient methods are not always the most profitable methods, for the margin of profit in dry-farming is normally small, and the cost of tillage must always be compared with the return. Efficiency in the use of the limited rainfall is, however, the basis upon which dry-farming practice must be built.

Before taking up the discussion of dry-farming investigations in the United States, a word regarding the organisation of the Department of Agriculture in this connection may be of interest. Five offices in the Bureau of Plant Industry are devoting a large part of their energies to dry-farming problems. The Office of Dry-Land Agriculture operates over a score of experimental farms in various sections of the Great Plains. This office is concerned chiefly with the determination of the crop rotations and tillage methods which are best adapted to the various dry-farming sections. It was early recognised in the development of this work that dry-farming problems are often of an extremely local character, and that numerous experimental stations are necessary to cover the field. Each experimental farm is superintended by a trained agriculturist, usually an agricultural college graduate. These farms also afford experimental facilities for other offices engaged in dry-farming problems. The offices of Cereal Investigations, Forage Crop Investigations, and Alkali and Drought-Resistant Plant Investigations are engaged in the investigations of crops suited to

dry-land conditions; while the Office of Biophysical Investigations, in co-operation with the above-named offices, is concerned with the study of the influence of various tillage methods on the absorption and retention of rainfall, the water requirement of crops under field conditions, and the influence of climatic conditions on the growth of dry-land crops. Over 50,000*l.* is now appropriated annually by Congress for the support of the dry-land work. In addition to this, several of the States are also conducting dry-farming investigations on an extensive scale, either independently or in co-operation with the Government. The field of investigation is so extensive that the present paper will be confined largely to the biophysical phases of the work.

Dry-Farming Areas in the United States.

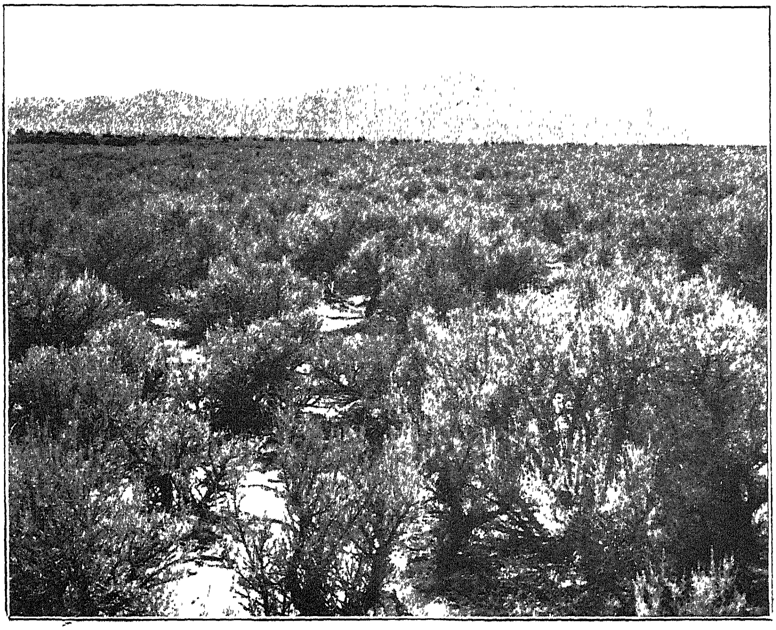
Two great dry-farming areas occur in the United States. One, the Intermountain area, lies between the Rocky Mountains on the east and the Sierra Nevada Mountains on the west. It is essentially a region of winter and spring rainfall. The other, the Great Plains area, extends from the Canadian boundary along the eastern side of the Rocky Mountains nearly to the Mexican boundary, and embraces over 200,000 square miles of land whose productivity is limited by the rainfall. This area, in contrast to the other, is a region of summer rainfall.

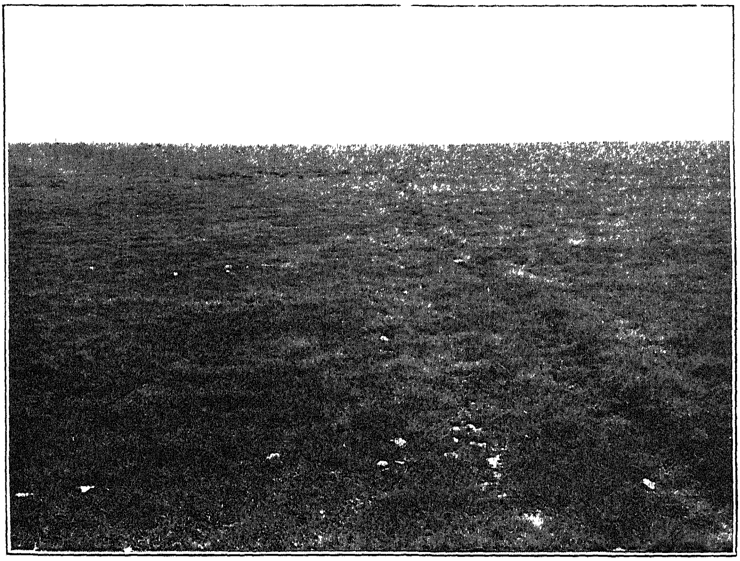
These two great areas differ greatly in their physiographic features and in their native plant cover. The Intermountain district is broken into numerous valleys, and the vegetation consists mainly of shrubby perennial plants, such as the sage-brush (*Artemisia tridentata*) (Plate V.) and a salt-bush (*Atriplex confertifolia*). The size and character of this vegetation affords a good index of the productivity of the land.[1] The larger the sage-brush the greater the water-supply and the better the farm. The soils occupied by salt-bush, on the other hand, are apt to be so saline in character as to be unsuited to dry-farming.

In the Great Plains no trees or shrubs are found except along the water-courses, while the gently undulating, grass-covered plain stretches unbroken to the horizon save for the buildings of the settlers. Much of this country is covered with buffalo grass (*Buchloë dactyloides*) and grama grass (*Boueteloua oligostachya*) (Plate V.), while farther to the east, where the rainfall is somewhat heavier, the taller bunch grass (*Andropogon scoparius*) and wire grass (*Aristida longiseta*) make their appearance.[2] This striking difference in the vegetation, characterised by the shrubby plants in the Intermountain districts and by grasses on the plains, reflects the difference in the distribution of the annual rainfall, which has had a marked effect upon the dry-farming development of the two sections.

[1] 'Indicator Significance of Vegetation in Tooele Valley, Utah,' Kearney, Briggs, Shantz, McLane, and Piemeissel, *Journal of Agricultural Research*, United States Department of Agriculture, **1**, p. 365, 1914.

[2] Shantz, H. L., *Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 201, 1911.





Showing the native sage-brush vegetation on virgin land in the Intermountain district (above), and the short-grass vegetation of the virgin Great Plains (below). The Intermountain district has a winter rainfall and the Great Plains a summer rainfall. (Photographed by H. L. Shantz.)

Illustrating the Report on Dry-Farming Investigations in the United States.

[*To face page* 264.

Rainfall.

It has become customary to use the average annual rainfall as a measure of the relative value of different areas for dry-farming purposes. Since the water-supply is usually the primary limiting factor, the annual rainfall must of course be emphasised. All who are engaged in dry-farming investigations recognise, however, the severe limitations of this classification. The seasonal distribution and the character of the rainfall—whether torrential or in the form of numerous light showers, or occurring as steady, soaking-rains—are often more important than the total annual rainfall in determining the productivity of a dry-farming region. The uncertainty of the rainfall should also be considered whenever sufficient statistical evidence is available.

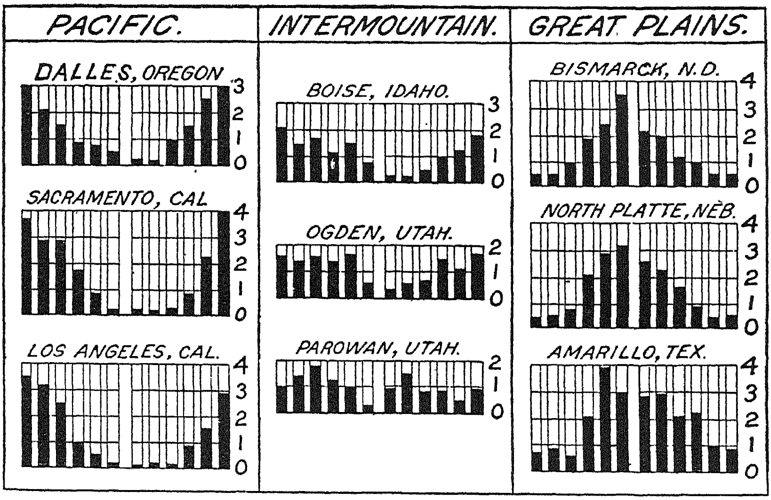


FIG. 1.—Chart showing the monthly distribution of the rainfall at representative stations in the Great Plains, Intermountain, and Pacific coast regions. The length of the black lines in each diagram represents the monthly precipitation at that place, beginning with January on the left. The scale in inches given on the right of each diagram can be used to find the actual amount of the monthly rainfall. For example, the average monthly rainfall at Bismarck, N. Dak., for June is seen to be $3\frac{1}{4}$ inches, while for July it is only a little more than 2 inches. It will be noted that in the Pacific coast region the rain comes principally at the beginning and end of the year, that is, in the winter; in the Intermountain districts during the winter and spring months; and in the Great Plains during the summer months.

Rainfall is not the only factor of importance, however. We shall refer later to the desirability of knowing the seasonal evaporation as measured from freely exposed tanks, which affords a summation of those factors which determine the rate of transpiration. The maximum temperatures and the wind velocity are also important factors. For an adequate comparison of widely separated dry-farming areas, a knowledge at least of the annual rainfall, its seasonal distribution, the

seasonal evaporation, and the depth and character of the soil appears to be indispensable.

Reference has already been made to the striking difference in the monthly distribution of the rainfall in the Great Plains as compared with the Intermountain districts. This difference is illustrated in fig. 1, which shows the monthly distribution of rainfall at representative stations in each area. Three Pacific Slope stations with a distinctly winter type of rainfall are also included. In this latter region, owing to the mildness of the climate, an annual crop of wheat is grown during the winter months either for grain or hay.

Grain-farming under the alternating fallow and cropping system has been satisfactorily established in Utah, where the annual rainfall is 13 inches or more. In the southern part of the State of Washington, where the conditions are unusually favourable, land with an annual rainfall as low as 10 inches is used for growing winter wheat by the summer-fallow method,[3] but the returns are uncertain. When the annual rainfall is reduced to 8·5 inches the crop will barely return the cost of production.

The rainfall required when the rain comes chiefly in the summer is higher than for winter rainfall. This appears to be due to the greater evaporation-loss from the fallow when wet frequently by summer rains. In the Great Plains, where a summer rainfall prevails, dry-farming is not successfully conducted on an annual rainfall less than 14 inches, and this minimum is still higher in the southern part of the area, due, as we shall see, to the higher rate of evaporation.

Evaporation.

The evaporation-rate may fairly be considered as ranking next in importance to the annual rainfall in determining the dry-farming possibilities of a region. The evaporation from a free-water surface represents a summation of the intensity of solar radiation, temperature, saturation-deficit, and wind velocity, all of which enter also into the determination of the transpiration-rate of the growing crop, though not necessarily in the same proportion as in free evaporation. Evaporation has been measured daily during the summer months at each of the experimental farms located in the dry-farming sections. Tanks 6 or 8 feet in diameter and 2 feet deep are used, the tanks being sunk in the ground to within four inches at the top. The free-water surface is maintained at ground-level, *i.e.*, about 4 inches from the top of the tank. Observations are now available for seven years at the stations first established. The observations are limited to the six months from April to September inclusive, since freezing weather is encountered at the stations during most of the remaining months. The average seasonal (April to September inclusive) evaporation in inches for each station, together with its location, is shown on the accompanying map (fig. 2). The evaporation increases rapidly as one proceeds southward in the Great Plains; the evaporation in Northern Texas, for example, is 54 inches, compared with 31 inches

[3] Briggs, L. J., and Belz, J. O., *Dry Farming in relation to Rainfall and Evaporation*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 188, p. 25.

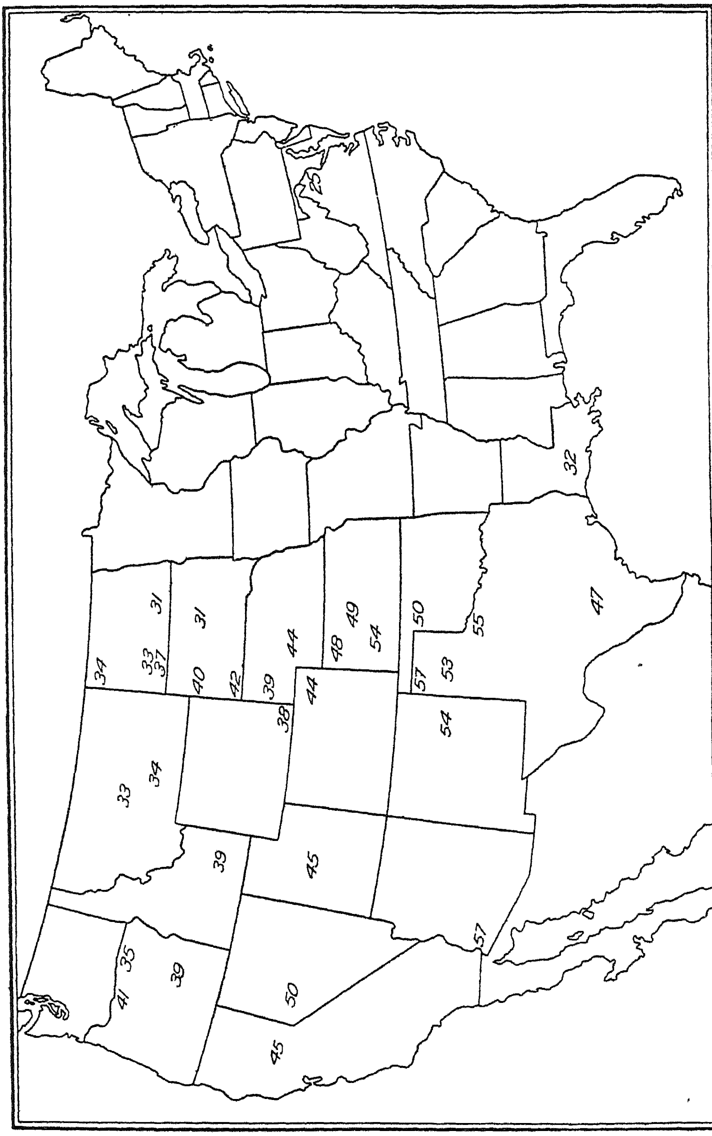


Fig. 2.—Map showing stations at which evaporation measurements are being made by the Office of Biophysical Investigations. The figures show the evaporation in inches during the six summer months (April to September inclusive). It will be seen the evaporation in the southern part of the Great Plains is nearly twice that in the northern part.

in the central part of North Dakota. Such differences have a profound influence upon the water-requirement of plants.

Shantz [4] has shown that under practically uniform soil conditions a pure short-grass formation is found in Northern Texas with an annual rainfall of about 21 inches; in Eastern Colorado with an annual rainfall of about 17 inches; and in Montana with an annual rainfall of approximately 14 inches. The region throughout has a summer rainfall. The same plant formation then requires 50 per cent. more rainfall in Northern Texas than in Montana. The explanation of this is to be found in the difference in the evaporation-rate in the two sections. Reference to fig. 2 will show that the evaporation in Northern Texas is approximately 60 per cent. higher than in Central Montana. A similar comparison between Northern Texas and North-Eastern Colorado shows that short-grass requires about approximately 27 per cent. more rainfall in Northern Texas, where the evaporation is 23 per cent. higher than in North-Eastern Colorado. The effectiveness of rainfall depends of course upon its penetration into the soil, so that any relationship which may be developed between evaporation and precipitation will necessarily be an approximate one. The above figures indicate, however, a rather close parallelism between the evaporation and the rainfall required to maintain a given plant formation, and emphasise the necessity of knowing the evaporation as well as the rainfall in judging the dry-farming possibilities of a region.[5]

A direct relationship between evaporation and water-requirement—*i.e.*, the pounds of water required by a plant in the production of a pound of dry matter—is shown in the following measurements by Briggs and Shantz of the water-requirement of the same strain of alfalfa when grown in different parts of the Great Plains (Table I.).

TABLE I.—*Water-requirement of Grimm alfalfa (second cutting) at different Stations in the Great Plains*, 1912.

Location	Growth period	Days	Water-requirement (to produce 1 lb. dry matter)		Evap. in inches	Daily Evap. in inches	Ratio of W.-R. to Daily Evap.
			lb.	oz.			
Williston, N.D.	July 29–Sept. 16	47	518	12	7·5	0·159	33
Newell, S.D.	Aug. 9–Sept. 24	46	630	8	8·6	0·187	34
Akron, Col.	July 26–Sept. 6	42	853	13	9·5	0·226	38
Dalhart, Tex.	July 26–Aug. 31	36	1005	8	11·0	0·306	34

It will be seen that the water-requirement increases steadily as one proceeds southward through the Great Plains, being twice as great in Northern Texas as in North Dakota. The daily evaporation

[4] Shantz, H. L., *Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 201, 1911, p. 12.

[5] Briggs, L. J., and Belz, J. O., Bureau of Plant Industry, Bulletin 188, 1911, p. 20.

also increases in a corresponding manner, so that the ratio of the water-requirement to the daily evaporation is approximately constant. Montgomery and Kiesselbach[6] have shown that maize grown in a dry house and in a humid house varied in its water-requirement exactly in proportion to the relative evaporation-rates in the two houses.

The water-requirement is not, however, always proportional to the evaporation. Other factors such as temperature may have a profound influence in determining the development of the plant. This may be illustrated by comparing the water-requirement of wheat and sorghum in Colorado and in Northern Texas (Table II.).[7] When the difference in evaporation is considered, sorghum is seen to have made a more efficient use of its water-supply in Texas than in Colorado, while the reverse is true in the case of wheat.

TABLE II.—*Comparison of the Relative Evaporation and of the Relative Water-requirement in the Great Plains in 1910 and 1911.*

Station	Year	Crop	Growing period	Evaporation		Water-requirement	
				Actual	Relative	Actual	Relative
Akron, Colo.	1910	wheat	April 18–Aug. 2	27·7	100	664	100
Amarillo, Tex.			April 5–July 19	34·0	122	853	128
Akron, Colo.	1910	sorghum	May 25–Sept. 28	33·0	100	356	100
Amarillo, Tex.			May 10–Aug. 28	37·7	114	359	101
Akron, Colo.	1911	wheat	May 13–Aug. 2	24·8	100	468	100
Dalhart, Tex.			April 25–July 18	28·5	115	673	143
Akron, Colo.	1911	sorghum	May 12–Sept. 4	35·0	100	298	100
Dalhart, Tex.			May 14–Sept. 12	41·9	120	313	105

Influence of the Distribution of Rainfall on Farm Practice.

The different distribution of the rainfall in the Intermountain district and the Great Plains has led to interesting differences in the farm practice of these regions.

Spring wheat is not a successful crop in the Intermountain district for two reasons: (1) The land cannot be fitted for sowing until late in the season, owing to the spring rains; and (2) the driest part of the season occurs when the spring wheat crop is maturing. A large acreage of winter wheat is, however, grown. In fact, the dry-farming activities of this section are devoted almost wholly to the growing of winter wheat. The stubble is not usually ploughed until spring, the land being very dry and hard in the fall. The stubble also keeps the winter snows from drifting and thus holds the precipitation on the land. As soon as the

[6] *Studies in the Water-requirement of Corn,* Nebraska Agricultural Experiment Station, Bulletin 128, 1912.

[7] Briggs, L. J., and Shantz, H. L., *Water-requirement of Plants, I.,* U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 284, p. 45

spring rains have ceased, the stubble and the early growth of weeds are turned under, and the land is kept fallow until the following autumn. The low rainfall during the summer makes it possible to destroy the weed-growth and maintain an efficient surface-mulch at a comparatively low cost. In the autumn, wheat is again sown. The crop makes a good part of its growth while the temperature is cool and the evaporation low, and in addition to the stored moisture has the advantage of the seasonal precipitation during its growth period.

One serious difficulty in dry-farming operations in regions of winter rainfall occurs in connection with the seeding of winter wheat on fallow land. The surface-mulch of the fallow is often dust-dry in the fall to a depth of 4 inches or more. If the farmer drills his grain in the dust, the seed remains inert until a rain occurs. If the first rain is insufficient in amount to soak through the dry mulch to the damp soil below, the seeds germinate, but the rootlets of the seedling plants do not reach the stored moisture below the intervening dry layer, and the plants soon die. On this account, farmers usually wait for fall rains before sowing wheat. If the seeding is thereby delayed until late in the fall, and freezing weather follows, the young plants are injured and weakened. And if this is followed by an 'open winter,' so that the wheat plants are not protected by a covering of snow, 'winter killing' is often very severe, and the crop is practically a failure.

Drilling the wheat to a depth sufficient to place the seed in moist soil would appear to be a possible solution of this problem, but this is often found impracticable, and the seedling plants have great difficulty in forcing their leaves to the surface. It is possible that a solution of the difficulty may be found in a seed-drill which has recently been developed, which throws the dry surface-soil in ridges, and plants the grain in moist soil at moderate depths in the intervening furrows. This plan is not practicable in windy regions, for the furrows would soon fill with dry soil.

In striking contrast with Intermountain practice, spring wheat is grown extensively in the Great Plains, especially in the central and northern part. The spring-sown crop escapes the dry fall and all danger from winter-killing, while the land, having been recently worked, is in better condition to absorb the summer rainfall. Intertilled crops are also grown to a much greater extent than in the Intermountain district, maize being especially popular in the northern part of the Great Plains, and the non-saccharine sorghums (milo, kafir, sorgo) in the southern part. The intertilled crop has in many sections largely taken the place of fallow, spring wheat now being extensively grown on disked corn-land.

Fallow is used extensively in the Great Plains, but the experiments by the Office of Dry-Land Agriculture, under the direction of E. C. Chilcott,[8] have shown that alternate cropping and summer tillage in many sections is less profitable than simple three-year rotations, especially those in which spring wheat is grown on disked corn-land, and even less profitable than continuous cropping. Summer tillage is not

[8] *A Study of Crop Rotations and Cultivation Methods for the Great Plains Area.* U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 187, p. 8, 1910.

so well adapted to a summer rainfall as to a winter precipitation, for the summer rains repeatedly pack the mulch, which necessitates frequent cultivation to keep the land in a receptive condition and to destroy the weeds which spring up after each rain. Summer tillage, however, affords some insurance against total loss of a crop during a dry season, which means disaster to the farmer with work-animals and cows to feed, and this element of insurance will doubtless always be a factor with the small farmer, even if summer tillage does not give the greatest returns.

Owing to the frequent high winds in the Plains, the blowing of the mulch on summer-tilled land sometimes becomes a serious problem. It is highly important in fallowing the Plains to keep the surface of the soil in a rough condition; in other words, to maintain a clod-mulch on the fallow rather than a dust-mulch, a practice which is also advantageous in the absorption of rainfall. On lands subject to blowing, the practice of cultivating in strips is sometimes followed. The strips are laid out at right angles to the prevailing winds, and alternating strips are planted to grain or an intertilled crop. Jardine[9] has recently emphasised the value of the lister in checking blowing in extreme cases. This implement opens a broad shallow furrow, throwing the dirt on both sides. Groups of two or three furrows each are listed at distances of from five to twenty rods across the field at right angles to the wind. The lister tends to form clods, while the disk harrow, except in moist ground, tends to pulverise the soil, and this must always be avoided in soils subject to blowing.

Depth of Root System in relation to Storage of Soil Moisture.

The great depth to which the roots of many of our cultivated plants extend has a very important bearing on the practicability of storing moisture in the soil. Burr[10] has found that oats, spring wheat, barley, and corn growing on the loess soils of Eastern Nebraska use the water to a depth of 4 feet or more, while winter wheat feeds to a depth of 6 or 7 feet. Excavations made in winter-wheat plats in Utah showed the root system to extend to a depth of 7 feet.[11]

In a soil which can store 6 per cent. of 'growth water,' there would be available in a section 6 feet in depth 600 tons of water per acre, or enough for the production of thirteen bushels of wheat in the central Great Plains.[12] For a root penetration of 4 feet, this amount would be reduced approximately one-third.

When the system of alternate cropping and fallowing is employed, water seldom moves below the zone occupied by the roots of the wheat plant. This has taken place, however, at the Dickinson experimental farm in western North Dakota. The water which moves below the feeding zone is practically lost to the plant, and remains undisturbed

[9] *Jour. Am. Soc. Agron.* 5, 213, 1913.
[10] Research Bulletin No. 5, Nebraska Experiment Station, 1914.
[11] Merrill, Bulletin 112, Utah Experiment Station, 1910.
[12] Briggs and Shantz, 'Relative Water-requirement of Plants,' *Jour. Agricultural Research*, U.S. Department of Agriculture, 3, 1, 1914.

from year to year. An argument often advanced in favour of deep-ploughing is that the depth of root penetration is thereby increased. The futility of this argument so far as dry-farm soils are concerned becomes evident when it is realised that the normal penetration of roots in the Intermountain and Great Plains soils is far below any depth that could possibly be reached with the plough. Deep ploughing may possibly increase the absorption-rate of rainfall when the precipitation-rate is so high as to saturate the surface soil temporarily, but this effect can also be secured by leaving the surface rough and corrugated when cultivating. Many of the field tests of the Office of Dry-Land Agriculture have failed to show any increase in yield from deep ploughing, an operation which means an added expense to an industry in which economy in labour must be rigidly exercised to show a reasonable profit.

Loss of Water from Weeds.

A relatively small proportion of the total annual rainfall is conserved in the fallow. The maximum quantity of stored moisture available for the crop seldom exceeds 4 inches of rainfall in sections where the annual rainfall ranges from 13 to 18 inches. This low efficiency is due in part to loss from run-off, but mainly to surface evaporation and to loss through the transpiration of weeds. Numerous measurements have shown that a rainfall of less than one-half-inch does not contribute to the permanent store of moisture in the soil unless the surface soil is already wet from previous rains. If the rainfall penetrates the soil below a depth of 6 inches, its rate of loss due to evaporation is low. But if the fallow is weedy, the stored water is lost through the transpiration of the plants almost as rapidly as if the moist subsoil were freely exposed to the air. The water-requirement of weeds is fully as high as some of our most valuable crop plants. For example, pigweed (*Amaranthus retroflexus*), tumble-weed (*Amaranthus græcizans*), and Russian thistle (*Salsola pestifer*) have a water requirement as high as the millets and sorghums, while sunflower (*Helianthus petiolarus*) and lamb's quarters (*Chenopodium album*) rank higher than many of the legumes.[13] The dry-farmer can, therefore, produce a valuable forage or grain crop with no greater expenditure of water per pound of dry matter than is lost through the weeds on his fallow.

Determinations by W. W. Burr[14] in Nebraska, R. W. Edwards[15] and J. G. Lill[15] in Kansas, and C. B. Burmeister[15] in Texas, all unite in showing that the evaporation loss from land from which the weeds are sliced off with a hoe is but little greater than from cultivated plants. In other words, cultivation is effective in conserving water mainly through the destruction of weeds rather than in the reduction of surface evaporation. This is well illustrated by Lill's measurements at Garden City, Kansas, as shown in fig 3. The

[13] Briggs and Shantz, *Jour. Agricultural Research,* U.S. Department of Agriculture, 3. 60, 1914.

[14] Research Bulletin No. 5, Nebraska Experiment Station, p. 61, 1914. In co-operation with the Office of Dry-Land Agriculture and Biophysical Investigations.

[15] Office of Dry-Land Agriculture in co operation with the Office of Biophysical Investigations.

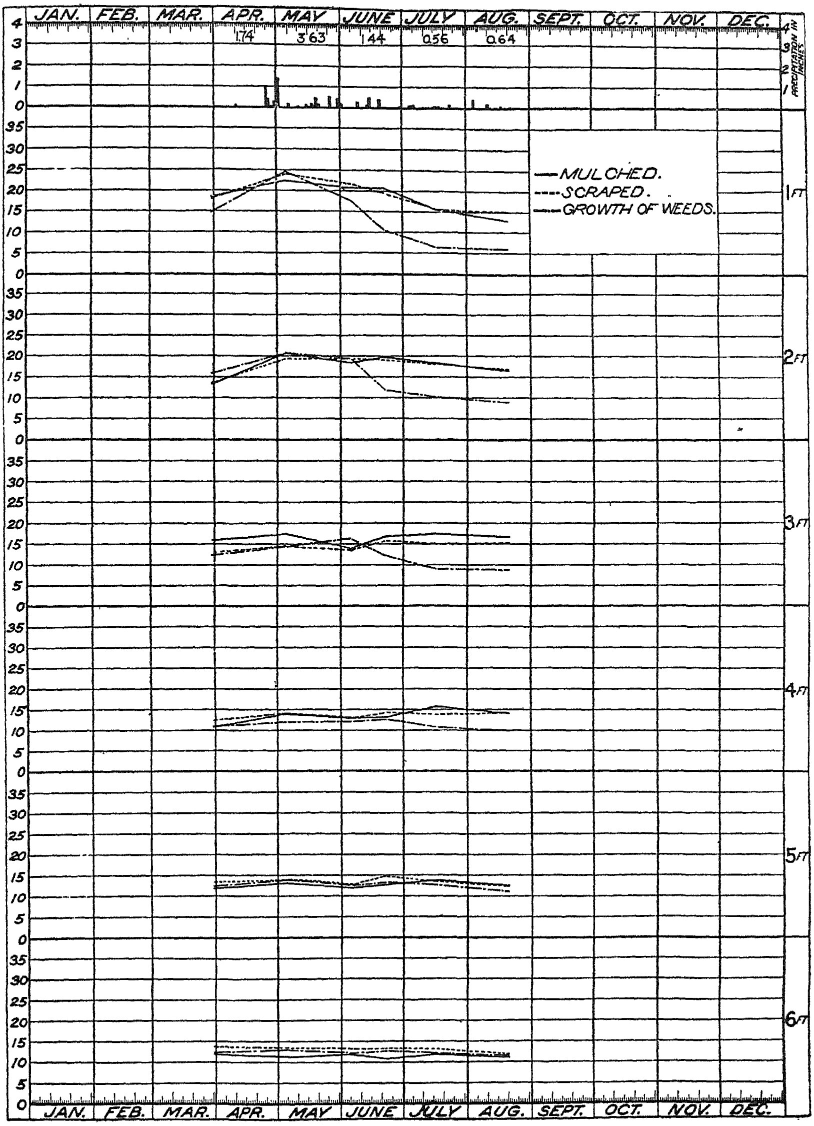


FIG. 3.—Loss of moisture from a mulched plat in comparison with a plat the surface of which has been scraped with a hoe to cut the weeds, and with a plat on which the weeds were allowed to grow. It will be seen that the mulched plat and the scraped plat differ little in effectiveness in conserving water, while the weeds reduce the moisture content to a depth of 3 feet.

moisture content of the mulched plat did not differ markedly from the plat on which the weeds were kept sliced off with a sharp hoe; while the plat on which the weeds were allowed to grow was dried out to a depth of 3 feet.

A striking example of the loss of moisture from weeds is also shown in experiments by P. V. Cardon, conducted at Nephi, Utah.[16] Winter wheat was grown on four plats by the summer fallow system, one-half the plats being in wheat each year. Two plats were fall-ploughed each year, and during the following summer, one plat was cultivated to destroy the weeds, while the other was left untouched except to clip the weeds in time to prevent the seeds maturing. In the autumn both plats were sown to winter wheat. The experiment was conducted for four years, and during this time the yield from the cultivated plat averaged four bushels more per acre than from the weedy plat.

The loss of moisture in these plats as the season advanced, due to the demand made by the weeds, is illustrated in the accompanying graphs, fig. 4. That this loss is primarily due to the weed cover and not to direct evaporation is supported by the fact that in other experiments at this station spring-ploughed uncultivated fallow on which the weed-growth was slight was practically as effective as cultivated fallow in conserving moisture. The average moisture content (6 feet in depth) of the weedy Nephi plat was at the time of the spring sampling 0·8 per cent. below the cultivated plat, and at the time of the Fall sampling 4·5 per cent. below the cultivated plat. This loss in moisture during the summer is equivalent to 3·5 inches of rainfall *stored in the soil*. This amount of water is sufficient, according to the water-requirement measurements of Briggs and Shantz,[17] to produce ten bushels of wheat per acre at Akron, Colorado, where the evaporation is the same as at Nephi. In 1911 the actual increase in yield of the cultivated plat over the weedy plat was eleven bushels per acre. During the other years the yield was reduced by winter killing, so that the water-supply was not the primary factor in determining production. Surely no more convincing proof is needed of the necessity of keeping fallow land free from weeds in regions where the moisture supply is of primary importance.

Growth-water.

It has long been known that a part of the soil-moisture is held so tenaciously that it is not available for the growth of plants. Sachs in 1859 appears to have been the first to recognise that the percentage of non-available moisture varies greatly with the type of soil. This is a matter of fundamental importance in the interpretation of soil-moisture observations, for the water unavailable for growth ranges from 1 per cent. or less in sand to 30 per cent. or more in the heaviest

16 Office of Cereal Investigations in Co-operation with the Office of Biophysical Investigations. See *Tillage and Rotation Experiments at the Nephi sub-station, Utah*, U.S. Department of Agriculture, Bulletin 157, 1914.

17 Briggs, L. J., and Shantz, H. L., 'Relative Water-requirement of Plants,' *Journal of Agricultural Research*, U.S. Department of Agriculture, 3, 1, 1914.

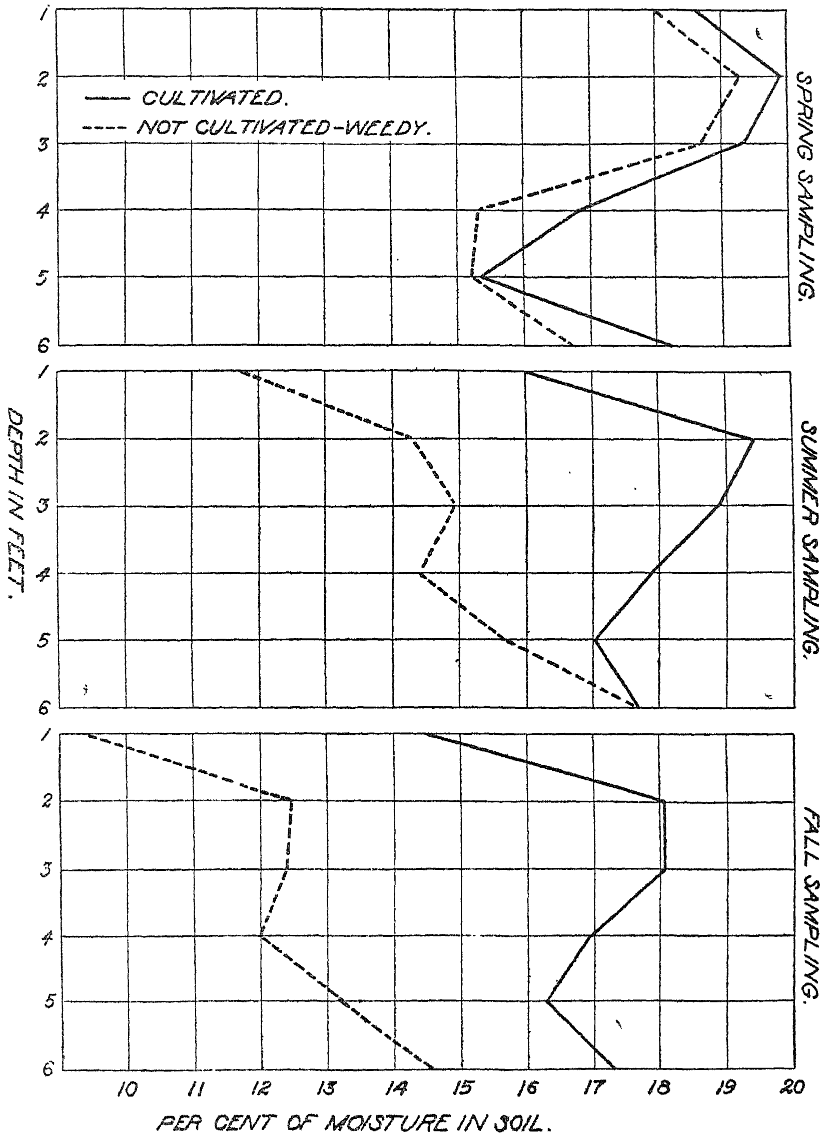


FIG. 4.—Loss of water from cultivated and weedy plats at Nephi, Utah, as the season advances.

types of clay.[18] Obviously, then, the percentage of water in the soil that is available for the growth of plants, or the 'growth-water' as Fuller[19] has termed it, cannot be determined until this unavailable residue is known.

Alway[20] has used the hygroscopic coefficient, *i.e.*, the percentage amount of water that a dry soil absorbs on exposure to a saturated atmosphere, to represent the unavailable portion. Briggs and Shantz[21] have measured the moisture-content at which plants undergo permanent wilting when growing in a limited soil mass, protected from surface evaporation. By permanent wilting is meant a condition from which the plants cannot recover when exposed to a saturated atmosphere.[22] The percentage of moisture remaining in the soil under such conditions has been termed the 'wilting coefficient' of that particular soil, and has been found to vary slightly with the kind of plant used as an indicator. The 'wilting coefficient' in connection with a total moisture determination provides a means for calculating the 'growth-water,' the latter being the surplus above the wilting coefficient. By the aid of such determinations it is possible to calculate the amount of stored growth-water—the bank-balance, so to speak, in the water account, against which the crop may draw.

It is not necessary always to measure the wilting coefficient directly, since it can be calculated from other physical properties of soils that can be more readily measured. Thus the moisture equivalent, hygroscopic coefficient, and mechanical composition have all been shown to bear a linear relationship to the wilting coefficient.[23] Of these indirect methods, that based on the moisture equivalent[24] is the most rapid and satisfactory. The latter represents the percentage of moisture remaining in the soil when brought into equilibrium with a centrifugal force 1,000 times that of gravity. The wilting coefficient is approximately one-half the moisture equivalent.

Where a small grain-crop has extended its root-system to a depth of 4 feet or more, the moisture-content of the second and third feet is sometimes reduced below the wilting coefficient. This is practically sure to occur if the crop is suffering for water, for plants are able to reduce the moisture-content far below the wilting coefficient while in a wilted condition, or during the ripening process. But it appears also to take place while the crop is still growing, provided the root-system is in contact with growth-water in some other part of the soil mass.[25]

[18] Briggs, L. J., and Shantz, H. L., *The Wilting Coefficient for Different Plants and its Indirect Determination*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 230, 1912, pp. 56–59.

[19] *Botanical Gazette*, **53**, p. 513, 1912.

[20] *Journal of Agricultural Science*, **2**, 1908, p. 334. [21] *Op. cit.*

[22] As the plant approaches a wilted condition its transpiration is reduced. Furthermore, as soon as wilting occurs it is necessary to transfer the plant to a saturated atmosphere, in order to determine whether the observed wilting is temporary or permanent. Consequently during the final stages of a wilting coefficient determination the transpiration rate is greatly reduced.

[23] Briggs and Shantz, *op. cit.*

[24] Briggs and McLane, *Jour. Am. Soc. Agron.* **2**, 1910, p. 138.

[25] Briggs, L. J., and Shantz, H. L., 'Application of Wilting Coefficient Determinations to Agronomic Investigations,' *Jour. Am. Soc. Agron.* **3**, 1911, p. 250.

SPRING WHEAT. AKRON, COLORADO, 1911. FALLOW. AKRON, COLORADO, 1912.

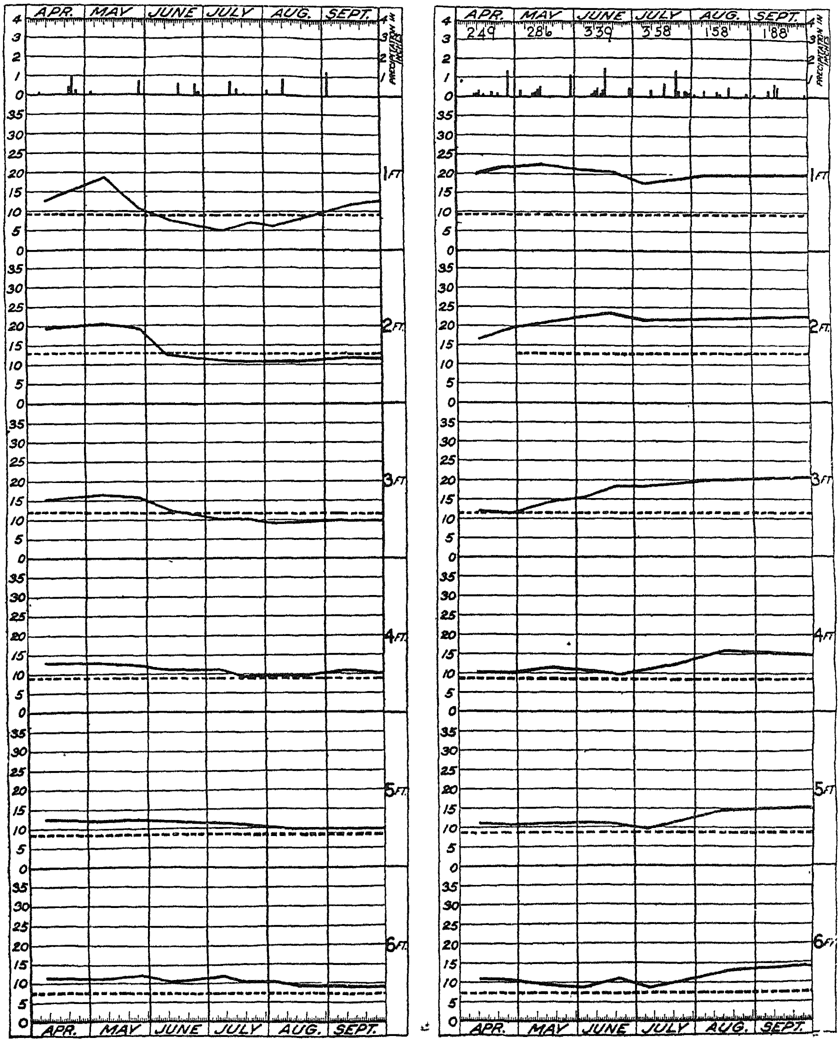


FIG. 5.—Moisture conditions in spring wheat and fallow plats at Akron, Colorado, to a depth of 6 feet. The dotted lines represent the wilting coefficient for each foot-section.

In other words, where the root-system is already established the crop is able to reduce the moisture-content below the wilting coefficient, and can use this to supplement the growth-water that it is drawing from lower levels. (*See* fig. 5, 1911.) On the other hand, crop-plants

show no tendency to send new roots into soil in which the moisture-content is reduced to the wilting coefficient. (*See* fig. 6, 1911.)

An example of the application of the wilting coefficient to the interpretation of moisture determinations is shown in the accompanying measurements by W. M. Osborne[26] at Akron, Colorado (fig. 5). The change in moisture during the season in each foot-section to a depth of 6 feet is shown graphically by the solid lines. The dotted lines represent the wilting coefficient for each foot-section. The first chart (1911) represents the moisture conditions under a crop of spring wheat during a dry season, the crop being practically a failure. It will be seen that in the spring there was available moisture in small amounts to a depth of 6 feet, the greater part being in the upper 3 feet. The crop had removed the growth-water from the first foot by June 1; from the second and third feet by June 15; from the fourth foot by July 15; while the fifth and sixth feet still contained a limited amount of growth-water at harvest time, although the moisture had been reduced in each case.

The second chart (1912) shows the moisture conditions in the same plat during the next summer while the land was in fallow. At the time the spring samples were taken the moisture-content of the surface foot of soil was practically up to the field-carrying capacity of this soil. With the advent of the seasonal rains the surface foot began to deliver to the section below. It will be noted that the change in moisture-content does not take place simultaneously through the soil-mass, but is progressive from foot to foot, each section delivering water to the section below as it rises to its field-carrying capacity. When the moisture supply is below a certain percentage, dependent upon the soil in question, capillary adjustment in that soil is very slow. Plants in order to avail themselves of all the growth-water must consequently develop a root-system which permeates the soil-mass from which water is being drawn. In other words, when the moisture supply is limited the capillary distribution becomes so slow as to be effective only through very small distances. Plants having a coarse root-system, such as maize, when used as indicator-plants, might be expected to give a somewhat higher wilting coefficient than plants with fine root-systems like the small grains, and this has been observed to be the case.[27]

The first chart in fig. 6 represents the moisture conditions as measured by J. C. Thysell[28] in a barley plat at Dickinson, North Dakota, during the dry season of 1911. This plat is normally seeded to barley each year. Inspection of the chart will show that at the beginning of the season the moisture-content of the second and third feet was at the wilting coefficient, to which it had been reduced by the preceding crop. A good supply of growth-water was present in the fourth, fifth, and sixth feet of the soil, but the roots were unable

[26] Office of Dry-Land Agriculture in Co-operation with the Office of Biophysical Investigations.

[27] Briggs and Shantz, *op. cit.*

[28] Office of Dry-Land Agriculture in Co-operation with the Office of Biophysical Investigations.

BARLEY. DICKINSON, N.D., 1911. BARLEY. DICKINSON, N.D., 1913.

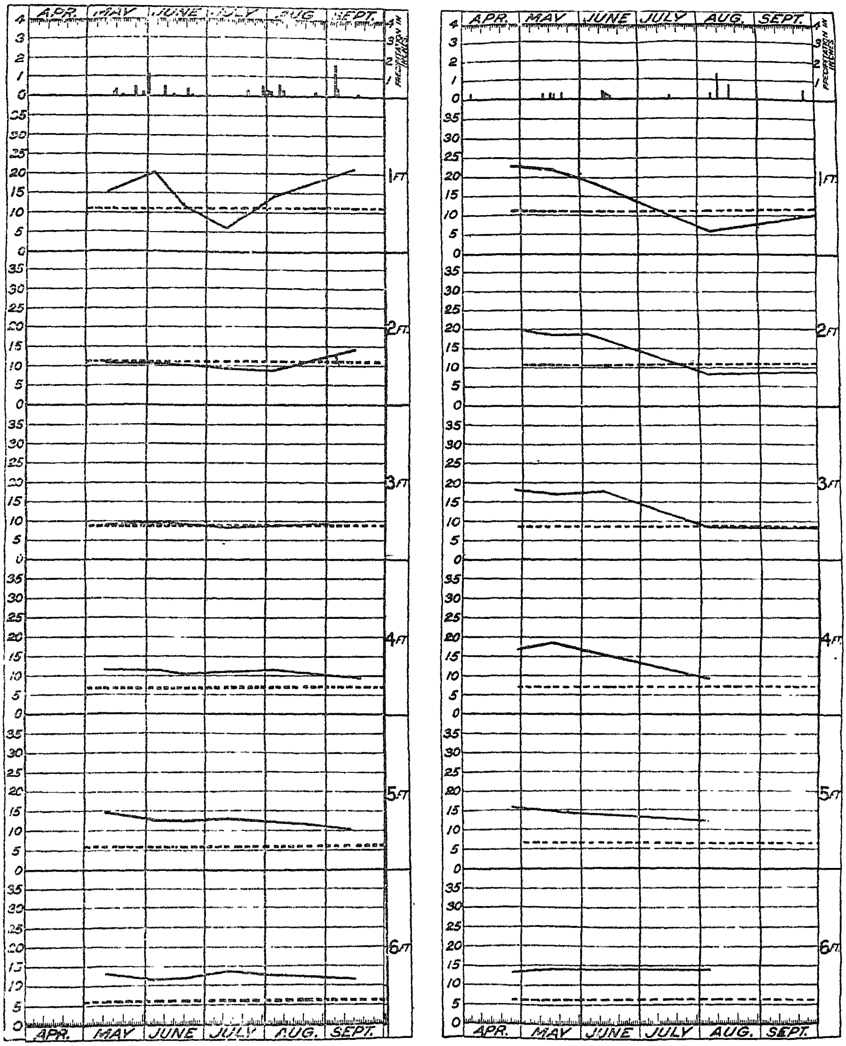


FIG. 6.—Moisture conditions in a barley plat at Dickinson, North Dakota. The dotted lines represent the wilting coefficient for each foot-section.

to penetrate the intervening dry layer, and the crop was a failure. In 1912 the crop was destroyed by hail, so that the plat was virtually in fallow during this season. The rainfall in 1912 was ample and the soil was well supplied with water in the spring of 1913, as shown in the second part of the chart. During this year a heavy crop of barley was grown, which was produced in part with water present in

the soil in 1911, but unavailable to the 1911 crop because the intervening soil was reduced to the wilting coefficient before the root system was established. It would be difficult to interpret these moisture conditions without the aid of the wilting coefficient determinations, especially where the moisture-retentivity of the soil and subsoil is not the same, as in the case of the Dickinson soils.

The growth-water content at seedtime and harvest in two plats at Akron, Colorado, is shown graphically in fig. 7 for six years. These plats form part of the cultural experiments of the Office of Dry-Land Agriculture, and are continuously cropped to spring wheat, A being spring-ploughed and B fall-ploughed. The width of the shaded portion in each foot-section shows the amount of growth-water. It will be noted that the growth-water was in every instance practically exhausted at harvest-time, with the exception of the surface-foot, which in some instances had been moistened by rains near the harvest period. It also appears that at this station the time of ploughing has little influence on the soil moisture-content.

Maintenance of the Fertility of the Dry-Farm.

The maintenance of fertility under a system of continuous grain-farming, such as is practised in many dry-farming sections, bids fair to become a more and more serious problem as the years advance. The period of cultivation of much of the dry-farm land has been so short as to afford no information on this point. In any event, it is hardly a problem that can be taken up with the man who breaks the virgin land. His first concern is for bread, and his chief desire is to draw upon the resources of his land to its fullest capacity. It is only after a marked decrease in production has occurred that he will listen to measures designed to maintain the fertility of the soil. Happily, grain-farming as practised on some of the oldest dry-farms in Utah does not yet appear to have diminished the productiveness of the soil. This is doubtless due in part at least to the fact that the wheat has been cut with a header (or more recently with a combined harvester), which leaves most of the straw on the land. Stewart and Hirst [29] have found that the humus and nitrogen content of the surface soil of the wheat lands farmed for ten years or more has not fallen below that of adjacent virgin soils. In an earlier investigation, Stewart [30] found that the oldest wheat lands in Utah, under cultivation for fourteen to forty-one years, either continuously or by summer-fallowing methods, had showed no loss in humus or nitrogen in the surface-foot. The second foot of the cultivated soils showed, however, a slightly lower nitrogen-content than the virgin land. The yield also appears to have been maintained.

A wanton waste of organic matter occurs in many dry-farming sections in the northern Great Plains and in California. The stubble is burned to make the ploughing easier and to destroy weed-seeds, and the straw-stacks are burned in the field because they are in the path of the ploughs. As the ploughing-season approaches, the horizon is

[29] *Jour. Am. Soc. Agron.* **6**, 49, 1914.
[30] Utah Experiment Station, Bulletin 109, 1910.

often lighted at night in every direction by the flames of the burning stacks. Even where the straw alone has been removed, grain-farming in the Great Plains has resulted in a marked decrease in the nitrogen and humus of the soil. Alway[31] has shown that the cultivation of the loess soils of Nebraska has been accompanied by a marked reduction in nitrates, total organic matter, and humus. He attributes

AVAILABLE SPRING AND HARVEST MOISTURE-CONTENT. AKRON, COLORADO.

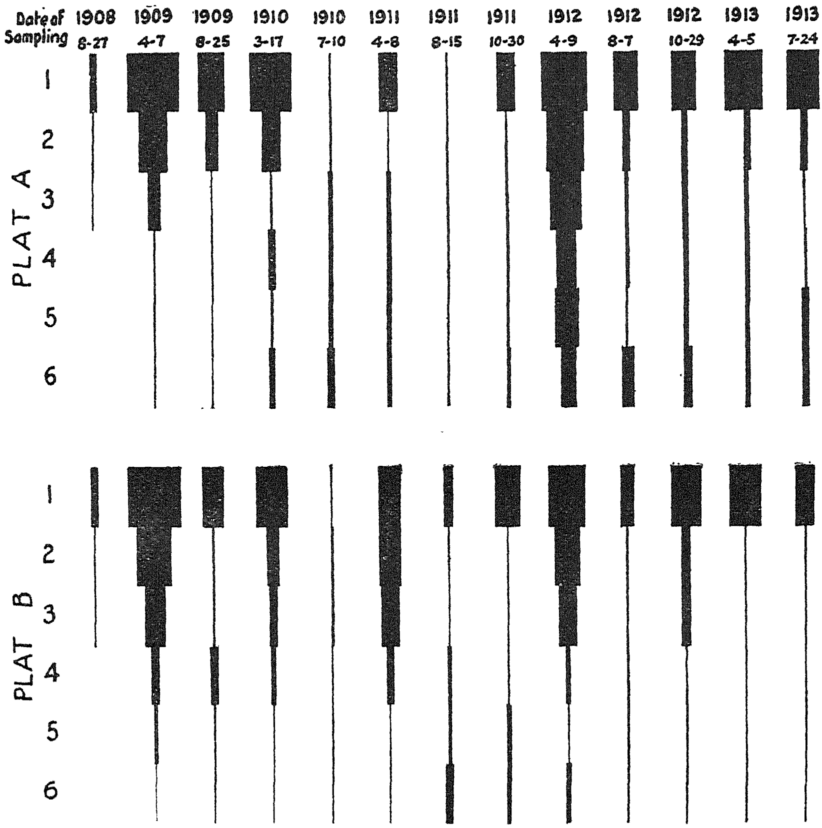


FIG. 7.—Growth-water at seed-time and harvest in spring-ploughed (A) and fall-ploughed (B) plats continuously cropped to grain.

the greatest loss of these components to the washing or blowing away of the surface soil.

Snyder[32] found that the loss of nitrogen from four Minnesota grain-farms in ten years was from four to six times that removed by the crops. This loss he attributes to the rapid breaking-up of the

[31] Bulletin 111, Nebraska Experiment Station, 1909.
[32] Bulletin 94, Minnesota Experiment Station, 1906.

humus under cultivation. Where legumes were grown, crop-rotations practised, live-stock kept, and the farm-manure used, the nitrogen content of the soil was maintained. This practice the dry-farmer of the Great Plains must eventually adopt as far as his conditions will permit, if a permanent agriculture is to be assured in these sections. The American dry-farmer has much to learn from Australian practice in the use of stock, especially sheep, on the dry-farm.

The Water-requirement of Different Dry-Farm Crops.

A word must be said in regard to the importance of considering the water-requirement of crops grown on the dry-farm. Other things being equal, those crops which are most efficient in the use of water are obviously best adapted to dry-land conditions. The great success of millet, sorghum, and maize in American dry-farming is due in part at least to their remarkable efficiency in the use of water. The amount of water required for the production of a pound of dry matter of some strains of alfalfa is four times that required by millet, where the two crops are growing side by side. Different varieties of the same crop often exhibit wide differences in water-requirement. The following figures represent the range in water-requirement due to varietal differences as measured by Briggs and Shantz [33] in the Great Plains.

TABLE III.—*Varietal Range in the Water-requirement of different Crops.*

Crop	Pounds water required to produce one pound of dry matter of the			
	Most efficient variety		Least efficient variety	
	lb.	oz.	lb.	oz.
Millet	261	15	444	9
Proso	268	1	341	10
Sorghum	285	3	467	9
Maize	315	3	413	5
Wheat	473	8	559	4
Barley	502	4	578	13
Oats	559	8	622	9
Clover	789	9	805	8
Alfalfa	651	12	963	9

These wide crop and varietal differences in water-requirement suggest great possibilities in the development of strains for dry-land conditions. In fact, the measurement of the water-requirement affords a novel and promising method of attack in the breeding and selection of dry-land crops.

[33] *Jour. Agricultural Research,* U.S. Department of Agriculture, **3**, 58, 1914.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section:
Professor F. T. Trouton, M.A., Sc.D., F.R.S.

Melbourne.

FRIDAY, AUGUST 14.

In the absence of the President, his Address was read by Professor A. W. Porter, F.R.S.:—

We have lost since the last meeting of the Section several distinguished members who have in the past added so much to the usefulness of our discussions. These include Sir Robert Ball, who was one of our oldest attendants, and was President of the Section at the Manchester Meeting in 1887; Professor Poynting, who was President of the Section at Dover in 1899; and Sir David Gill, who was President of the Association at Leicester in 1907.

It seems appropriate at this meeting in the City of Melbourne to mention one who passed away from his scientific labours somewhat previous to the last meeting. I allude to W. Sutherland of this city, whose writings have thrown so much light on Molecular Physics and whose scientific perspicacity was only equalled by his modesty.

This meeting of the British Association will be a memorable one as being indicative, as it were, of the scientific coming of age of Australia. Not that the maturity of Australian science was unknown to those best able to judge; indeed the fact could not but be known abroad, for in England alone there are many workers in science hailing from Australia and New Zealand, who have enhanced science with their investigations and who hold many important scientific posts in that country. In short, one finds it best nowadays to ask of any young investigator if he comes from the Antipodes.

This speaks well for the Universities and their staffs, who have so successfully set the example of scientific investigation to their pupils.

Radio-activity and kindred phenomena seem to have attracted them most of late years, and it would perhaps have been appropriate to have shortly reviewed in this address our knowledge in these subjects, to which the sons of Australasia have so largely contributed.

Twenty-five years ago FitzGerald and others were speculating on the possibility of unlocking and utilising the internal energy of the atom. Then came the epoch-making discovery of Becquerel, to be followed by the brilliant work of Rutherford and others showing us that no key was required to unlock this energy—the door lay open.

We have still facing us the analogous case of a hitherto untapped source of energy arising from our motion through the ether. All attempts, it is true, to realise this have failed, but nevertheless he would be a brave prophet who would

deny the possibility of tapping this energy despite the ingenious theories of relativity which have been put forward to explain matters away. There is no doubt but that up to the present nothing hopeful has been accomplished towards reaching this energy and there are grave difficulties in the way; but 'Relativity' is, as it were, merely trying to remove the lion in the path by laying down the general proposition that the existence of lions is an impossibility. The readiness with which the fundamental hypotheses of 'Relativity' were accepted by many is characteristic of present-day Physics, or perhaps, more correctly speaking, is an exaggerated example of it.

Such an acceptance as this could hardly be thought of as taking place half-a-century ago, when a purely dynamical basis was expected for the full explanation of all phenomena, and when facts were only held to be completely understood if amenable to such treatment; while, if not so, they were put temporarily into a kind of suspense account, waiting the time when the phenomenon would succumb to treatment based on dynamics.

Many things, perhaps not the least among them radio-activity, have conspired to change all this and to produce an attitude of mind prepared to be content with a much less rigid basis than would have been required by the Natural Philosophers of a past generation. These were the sturdy Protestants of Science, to use an analogy, while we of the present day are much more catholic in our scientific beliefs, and in fact it would seem that nowadays to be used to anything is synonymous with understanding it.

Leaving, however, these interesting questions, I will confine my remarks to a rather neglected corner of physics, namely, to the phenomena of Absorption and Adsorption of solutions. The term Adsorption was introduced to distinguish between Absorption which takes place throughout the mass of the absorbing material and those cases in which it takes place only over its surface. If, for instance, glass, powdered so as to provide a large surface, is introduced into a solution of a salt in water, we have in general some of the salt leaving the body of the solution and adhering in one form or other to the surface of the glass. It is to this the term Adsorption has been applied. Physicists have now begun to take up the question seriously, but it was to Biologists, and especially Physiological Chemists, that most of our knowledge of the subject in the past was due, the phenomenon being particularly attractive to them, seeing that so many of the processes they are interested in take place across surfaces.

As far as investigations already made go the laws of Adsorption appear to be very complicated, and no doubt many of the conflicting experimental results which have been obtained are in part due to this, workers under somewhat different conditions obtaining apparently contradictory effects.

On the whole, however, it may be said that the amount adsorbed increases with the strength of solution according to a simple power law, and diminishes with rise of temperature; but there are many exceptions to these simple rules. For instance, in the case of certain sulphates and nitrates the amount adsorbed by the surface of, say, precipitated silica only increases up to a certain critical point as the strength of the solution is increased. Then further increase in the strength of the solution causes the surface to give up some of the salt it has already adsorbed, or the amount adsorbed is actually less now than that adsorbed from weaker solutions. Beyond this stage for still greater concentrations of the solutions the amount adsorbed goes on increasing as before the critical point was reached.

There is some reason for thinking that there are two modes in which the salt is taken up or adsorbed by the solid surface. The first of them results from a simple strengthening of the solution in the surface layers; the second, which takes place with rather stronger concentrations, is a deposition in what is apparently analogous to the solid form. It would seem that the first reaches out from the solid surface to about 10^{-8} cm.—which is the order of the range of attraction of the particles of the solid substance.

The cause of the diminution in the adsorption layer at a certain critical value of the concentration is difficult to understand. Something analogous has been observed by Lord Rayleigh in the thickness of layers of oil floating on the surface of water. As oil is supplied the thickness goes on increasing up to a certain point; beyond this, on further addition of oil, the layer thins itself at some

places and becomes much thicker at others, intermediate thicknesses to these being apparently unstable and unable to exist. As helping towards an explanation of the diminution in the adsorption layer, we may suppose that as the strength of the solution is increased from zero, the adsorption is at first merely an increased density of the solution in the surface layer. For some reason, after this has reached a certain limit, further addition of salt to the solution renders this mode of composition of the surface layers unstable, and there is a breaking up of the arrangement of the layer with a diminution in its amount. We may now suppose the second mode of deposition to begin to show its effect with a recovery in the amount of the surface layers and a further building up of the adsorption deposits.

On account of passing through this point of instability the process is irreversible, so that the application of thermo-dynamics to the phenomenon of adsorption is necessarily greatly restricted in its usefulness.

A possible cause of the instability in the adsorption layer which occurs at the critical point may be looked for in the alternations in the sign of the mutual forces between attracting particles of the kind suggested by Lord Kelvin and others. Within a certain distance apart—the molecular range—the particles of matter mutually attract one another, while at very close distances they obviously must repel, for two particles refuse to occupy the same space. At some intermediate distances the force must pass through zero value. It has for various reasons been thought that, in addition, the force has zero value at a second distance lying between the first zero and the molecular range, with accompanying alternations in the sign of the force. Thus, starting from zero distance apart of the particles, the sign of the force is negative or repulsive; then, as the distance apart is supposed to increase, the force of repulsion diminishes, and after passing through zero value becomes positive or attractive; next, as the distance is increased the force diminishes again, and after passing through a second zero becomes negative for a second time; finally, the force on passing through a third zero becomes positive, and is then in the stage dealt with in capillary and other questions.

As an instance of where these alternations of sign seem to be manifest, may be mentioned the case of certain crystals when split along cleavage planes. The split often runs along further than the position of the splitting instrument or inserted wedge seems to warrant. This would occur if the particles on either side of the cleavage plane were situated at the distance apart where the force between them was in the first attractive condition, for then, on increasing the distance between the particles by means of the wedge, the force changes sign and becomes repulsive, thus helping the splitting to be propagated further out.

Assuming that a repulsive force can supervene between the particles in the adsorption layer, through the particles becoming so crowded in places as to reduce their mutual distances to the stage when repulsion sets in, we might expect that an instability would be set up.

As already stated, a rise in temperature reduces in general the amount adsorbed, but below the critical point the nitrates and sulphates are exceptional, for rise in temperature here increases the amount adsorbed from a given solution. This obviously necessitates that the isothermals cross one another at the critical point in an Adsorption-Concentration diagram. This may perhaps account for some observers finding that adsorption did not change with temperature. We have another exception to the simple laws of adsorption in the case of the alkali chlorides; this exception occurs under certain conditions of temperature and strength of solution. The normal condensation into the surface layer is reversed and the salt is repelled into the general solution instead of being attracted by the surface. In other words, it is the turn of the other constituent of the solution, namely, the water, to be adsorbed.

It is a very well known experiment in adsorption to run a solution such as that of permanganate of potash through a filter of sand, or, better, one of precipitated silica, so as to provide a very large surface. The first of the solution to come through the filter has practically lost all its salt owing to having been adsorbed by the surface of the sand.

I was interested in finding a few months ago that Defoe, the author of 'Robinson Crusoe,' in one of his other books, depicts a party of African travellers

as being saved from thirst in a place where the water was charged with alkali by filtering the water through bags of sand. Whether this is a practical thing or not is doubtful, or even if it has ever been tried; for it is only the first part of the liquid to come through the filter which is purified, and very soon the surface has taken up all the salt it can adsorb, and after that, of course, the solution comes through intact. It is interesting, however, to know that so long ago as Defoe's time the phenomenon of adsorption from salt solutions had been observed. It is not so well known that in the case of some salts under the circumstances mentioned above, the first of the solution to come through the sand filter is stronger instead of weaker. This, as already mentioned, is because water, or at least a weaker solution, forms the adsorption layer.

Most of the alkali chlorides as the temperature is raised show this anomalous adsorption, provided the strength of the solution is below a certain critical value differing for each temperature. For strengths of solution above these values the normal phenomenon takes place.

No investigations seem to have been made on the effect of pressure on adsorption. These data are much to be desired.

The investigation of adsorption and absorption should throw light on Osmosis, as in the first place the phenomenon occurs across a surface necessarily covered with an adsorption layer, and in the second place, as we shall see, the final condition is an equilibrium between the absorption of water by the solution and that by the membrane.

The study of the conditions of absorption of water throughout the mass of the colloidal substance of which osmotic membranes are made is of much interest. Little work has been done on the subject as yet, but what little has been done is very promising

It is convenient to call the material of which a semi-permeable membrane is made the semi-permeable medium. The ideal semi-permeable medium will not absorb any salt from the solution, but only water, but such perfection is probably seldom to be met with. If a semi-permeable medium such as parchment paper be immersed in a solution, say, of sugar, less water is taken up or absorbed than is the case when the immersion is in pure water. The diminution in the amount absorbed is found to increase with the strength of the solution. It is at the same time found that the absorption or release of water by the semi-permeable medium according as the solution is made weaker or stronger is accompanied by a swelling or shrinkage greater than can be accounted for by the water taken up or rejected.

The amount of water absorbed by a semi-permeable medium from a solution is found by experiment to depend upon the hydrostatic pressure. If the pressure be increased the amount of water absorbed by the semi-permeable medium is increased. It is always thus possible by the application of pressure to force the semi-permeable medium to take up from a given solution as much water as it takes up from pure water at atmospheric pressure.

It is not possible for a mass of such a medium to be simultaneously in contact and in equilibrium with both pure water and with a solution all at one and the same pressure, seeing that the part of the medium in contact with the pure water would hold more water than that part in contact with the solution, and consequently diffusion would take place through the mass of the medium.

If, however, the medium be arranged so as to separate the solution and the water, and provided the medium is capable of standing the necessary strain, it is possible to increase the pressure of the solution without increasing the pressure of the water on the other side. Thus the part of the medium which is in contact with the solution is at a higher pressure than that part in contact with the pure solvent; consequently the medium can be in equilibrium with both the solution and the solvent, for if the pressures are rightly adjusted the moisture throughout the medium is everywhere the same.

The ordinary arrangement for showing osmotic pressure is a case such as we are considering, and equilibrium throughout the membrane is only obtained when the necessary difference in pressure exists between the two sides of the membrane.

This condition would eventually be reached no matter how thick the membrane was. It is sometimes helpful to think of the membrane as being very

thick. It precludes any temptation to view molecules as shooting across from one liquid to the other through some kind of peepholes in the membrane.

The advantage of a thin membrane in practice is simply that the necessary moisture is rapidly applied to the active surface, thus enabling the pressure on the side of the solution to rise quickly, but it has no effect on the ultimate equilibrium.

As far as that goes, the semi-permeable membrane or saturated medium might be infinitely thick, or, in other words, there need be no receptacle or place for holding the pure solvent outside the membrane at all. In fact, the function of the receptacle containing the pure solvent is only to keep the medium moist, and is no more or no less important than the vessel of water supplied to the gauze of the wet-bulb thermometer. It is merely to keep up the supply of water to the medium.

The real field where the phenomenon of osmosis takes place is the surface of separation between the saturated semi-permeable medium and the solution. Imagine a large mass of colloidal substance saturated with water and having a cavity containing a solution. The pressure will now tend to rise in the cavity until it reaches the osmotic pressure—that is, until there is established an equilibrium of surface transfer of molecules from the solution into the medium and back from the medium into the solution.

No doubt, the phenomenon as thus described occurs often in Nature. It is just possible that the high-pressure liquid cavities which mineralogists find in certain rock crystals have been formed in some such manner in the midst of a mass of semi-permeable medium; the pure solvent in this case being carbon dioxide and the medium colloidal silica, which has since changed into quartz crystal.

In considering equilibrium between a saturated semi-permeable medium and a solution there seems to me to be a point which should be carefully considered before being neglected in any complete theory. That is, the adsorption layer over the surface of the semi-permeable medium. We have seen that solutions are profoundly modified in the surface layers adjoining certain solids, through concentration or otherwise of the salts in the surface layer, so that the actual equilibrium of surface transfer of water molecules is not between the unmodified solution and the semi-permeable medium, but between the altered solution in the absorption layer and the saturated medium. Actual determinations of the adsorption by colloids are much wanted, so as to be able to be quite sure of what this correction amounts to or even if it exists. It may turn out to be zero. If there is adsorption, however, it may possibly help to account for part of the unexpectedly high values of the osmotic pressure observed at high concentrations of the solution, the equilibrium being, as we have seen, between the saturated medium and a solution of greater concentration than the bulk of the liquid, namely, that of the adsorption layer. In addition, when above the critical adsorption point, there may be a deposit in the solid state. This may produce a kind of polarised equilibrium of surface transfer in which the molecules which discharge from the saturated medium remain unaltered in amount, but those which move back from the adsorption layer are reduced owing to this deposit, thus necessitating an increase in pressure for equilibrium. If either or both of these effects really exist, it would seem to require that the pressure should be higher for equilibrium of the molecular surface transfer than if there were no adsorption layer and the unaltered solution were to touch the medium, but at the same time it should be remembered that there is a second surface where equilibrium must also exist—that is, the surface of separation of the adsorption layer and the solution itself. It is just possible that the two together cancel each other's action.

Quantitative determinations of absorption by solid media from solution are hard to carry out, but with a liquid medium are not so difficult. Ether constitutes an excellent semi-permeable medium for use with sugar solution, because it takes up or dissolves only a small quantity of water and no sugar. A series of experiments using these for medium and solution has shown (1) that the absorption of water from a solution diminishes with the strength of the solution; and (2) that the absorption of water for any given strength of solution increases with the pressure. This increase with pressure is somewhat more rapid than if it

were in proportion to the pressure. On the other hand, from pure water ether absorbs in excess of normal almost in proportion to the pressure. Certainly this is so up to 100 atmospheres. This would go to confirm the suggestion already made that the departure from proportionality in the osmotic pressure is attributable to absorption.

By applying pressure ether can be thus made to take up the same quantity of water from any given solution as it takes up from pure water at atmospheric pressure. It is found by experiment that this pressure is the osmotic pressure proper to the solution in question.

Decidedly the most interesting fact connected with the whole question of osmotic pressure, the behaviour of vapour pressures from solution, and the equilibrium of molecular transfer of solutions with colloids, is that discovered by van 't Hoff, that the hydrostatic pressure in question is equal to what would be produced by a gas having the same number of particles as those of the introduced salt. Take the case of a mass of colloid or semi-permeable medium placed in a vessel of water; the colloid when in equilibrium at atmospheric pressure holds what we will call the normal moisture. By increasing the pressure this moisture can be increased to any desired amount. Now, on introducing salt the moisture in the colloid can be reduced at will. The question is, What quantity of salt must be introduced just to bring back the amount of the moisture in the colloid to normal? Here we get a great insight into the internal mechanism of the liquid state. The quantity of salt required turns out to be, approximately at least, that amount which if in the gaseous state would produce the pressure. So that normality can be either directly restored by removing the pressure or indirectly by introducing salt in quantity which just takes up the applied pressure. That this is so naturally suggested that the salt, although compelled to remain within the confines of the liquid, nevertheless produces the same molecular bombardment as it would were it in the gaseous state, though of course the free path must be viewed as enormously restricted compared with that in the gaseous state.

Many have felt a difficulty in accepting this view of a molecular bombardment occurring in the liquid state, but of recent years much light has been thrown on the subject of molecular movements in liquids, especially by Perrin's work, so that much of the basis of this difficulty may be fairly considered as now removed.

Quite analogous to the reduction from the normal of the moisture held by a semi-permeable medium brought about by the addition of salt to the water, is the reduction in the vapour pressure arising from the presence of a salt in the water. The vapour pressure is likewise increased by the application of hydrostatic pressure, which may be effected by means of an inert gas. In both cases the hydrostatic pressure which must be applied to bring back to normality is equal to that which the added salt would exert if it were in the state of vapour, or, in other words, the osmotic pressure.

The two cases are really very similar. In both there is equal molecular transfer backwards and forwards across the bounding surface. In the one a transfer from that solution to the semi-permeable medium and back from it into the solution. In the other a transfer from the solution into the superambient vapour and back from it into the solution.

The processes are very similar, namely, equal molecular transfer to and fro across the respective surfaces of separation.

Thus we may in the case of osmotic equilibrium attribute the phenomenon with Callender to evaporation, but not evaporation in its restricted sense, from a free surface of liquid, but as we have seen from a saturated collodial surface into the solution. This process might perhaps be better referred to as molecular emigration, the term migration being already a familiar one in connection with liquid phenomena.

The following Report and Papers were then read :—

1. *Report of the Committee to Aid in Establishing a Solar Physics Observatory in Australia.*—See Reports, p. 74.

2. *Mount Stromlo Observatory.* By P. Baracchi.

The Government of the Commonwealth, wishing to define a spot within the Federal Territory the meridian of which should be adopted as the Prime Meridian of Australia, to serve as the common longitude datum for all State surveys, decided to mark the spot by erecting upon it a small astronomical observatory which, if the selected site proved to be sufficiently good for the most delicate and important class of astronomical observation and research, was to be expanded and equipped as a modern observatory of the first order, including a department for the study of the sun.

The site was selected in the year 1910; a concrete structure with an eighteen-foot dome was subsequently erected, and a nine-inch refractor by Grubb, equatorially mounted, was installed in September 1911.

With this instrument astronomical observations, visual, photographic and spectroscopic, were carried out during one week of each month in the year 1912 and till April 1913, after which sufficient evidence was collected to show that the site was suitable for a first-class observatory.

Since then this observatory has remained inoperative pending the decision of the Government as to its future.

In this paper the site of the observatory, the instruments, and the work done were briefly described, with the object of placing sufficient information about this matter before the British Association to enable it to recommend to the Commonwealth Government the general lines on which this observatory should be enlarged and equipped, and what should be the programme of its future work.

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3. *Proofs of the Sun's Variability.* By C. G. Abbot.

It has been shown by experiments of the Smithsonian Astrophysical Observatory conducted simultaneously at Mount Wilson in California and Bassour in Algeria, in the years 1911 and 1912, that the values of the intensity of the solar radiation outside the atmosphere estimated by spectrobolometric observations at the two stations on the same days are, within the limits of error, identical. The measurements at the two stations agreed within an average deviation of about 1 per cent. It appeared, however, that the values of the solar constant of radiation obtained deviated over a range of nearly 10 per cent. during the continuance of the expeditions. This deviation was observed at both stations, so that if high values were obtained in California high values were obtained simultaneously in Algeria, and *vice versa.* Professor Turner has computed, from the observations, the coefficient of correlation between the results at the two stations. He finds this coefficient to be 52 per cent. plus or minus 7 per cent. if all the observations are used. Rejecting three observations of extreme doubtfulness, the correlation coefficient rises to 60 per cent. This furnishes very strong evidence of the variability of the sun, which appears to be irregular in period and irregular in amplitude, but may range over a course of 5 per cent. or even more within the lapse of a week.

Measurements of the solar constant of radiation have been conducted on Mount Wilson in California by the Smithsonian Astrophysical Observatory for about eight years, though unfortunately the observations have been confined to the months of summer and autumn, when the sky is favourable there for them. It is highly important that such work should be taken up at another station, or preferably at several other stations, where favourable conditions of the sky would be found in the other months of the year.

When the monthly mean values of the solar constant as obtained on Mount Wilson are compared with the sun-spot numbers of Wolfer, it is found that increased sun-spot numbers correspond with increased values of the solar radiation and *vice versa.* Professor Turner has computed the correlation coefficient for these two variables as depending upon fifty months of observations, and finds this coefficient to be 53 per cent. plus or minus 7 per cent. Here also it is seen that a strong proof of the variability of the sun's radiation exists. It appears therefore that the sun, besides varying from day to day in the manner shown by the combined Algerian and Mount Wilson observations, also varies from year to year in connection with the march of the sun-spot cycle.

In September 1913 a tower telescope, forming the image of the sun by the use of mirrors without lenses, and yielding an image of about 9 inches in diameter, was made ready in connection with the station of the Smithsonian Astrophysical Observatory on Mount Wilson. The image of the sun is caused to fall upon the slit of a spectrobolometer, which slit for this purpose is only about three-eighths of an inch in height. By stopping the clock of the telescope the solar image drifts centrally across the slit of the spectrobolometer, owing to the diurnal rotation of the earth. There is thus produced, by automatic registering of the indications of the bolometer, a curve of distribution of intensity along the diameter of the sun's disk. This curve takes the form of a letter U. The length of the straight sides of the U may be taken as representing the intensity of the solar radiation at the edge of the sun's disk, and the height of the U to the centre of the curve may be taken as representing the intensity of the radiation at the centre of the disk. Thus a contrast of the intensity of radiation along the diameter of the sun is made manifest. Observations were made on nearly fifty days of the year 1913 with this apparatus, and on each day the distribution of intensity at seven different wave-lengths of the spectrum between 3,700 Ångströms and 10,000 Ångströms was determined by making two curves at each wave-length. On the same days the solar constant of radiation was determined at Mount Wilson.

Work with a similar object, but done in different ways, has been carried on by Vogel, Pickering, Langley, Very, Schwarzschild and Villager, and Abbot and Fowle. It is found by comparison of the distribution curves obtained at Mount Wilson in 1913 with others obtained by Abbot and Fowle in 1907, that a change of form of the distribution curve has occurred between these epochs. The contrast of brightness between the centre and edge of the sun in the year 1907 was greater than the contrast found in the year 1913. This is verified at all wave-lengths, but the change of contrast is greater for short wave-lengths than for longer ones.

It further appears, by comparison of results of one day with another in the year 1913, that a change of contrast of brightness is going on all the time, similar in irregularity of period and amplitude with the variation of the sun's total radiation which was found by comparison of Mount Wilson and Bassour observations. When the daily values of the solar constant of radiation obtained in 1913 are compared with the distribution of brightness along the sun's diameter, it is seen that a close correspondence of variation occurs between the two. This daily variation is of such a nature that when the solar constant values increase the constant of brightness between the centre and edge of the sun diminishes. The result is contrary to that which was indicated by a few observations of Abbot and Fowle in the year 1908. It is believed on further examination that the results of Abbot and Fowle in 1908 were made erroneous by certain defects in the measurements of the solar constant of radiation on two or three days. The new results come from nearly fifty days of observation, and are quite definite in showing the connection between the variation of the radiation of the sun and the variation of brightness along the sun's diameter.

It appears, however, that the correlation between solar constant values and contrast values between the years 1907 and 1913 is contrary in its sign to the correlation between these variables exhibited by the daily march of values for the year 1913. This may point to a greater complexity of the solar problem than was at first indicated by the results of Abbot and Fowle. It may be that the march of the sun-spot period attends an influence in one direction, while the march of short-period fluctuations of the solar radiation from day to day attends a change of contrast in the other direction.

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4. *Discussion on the Present State of the Problem of Australian Longitudes. Opened by* P. Baracchi.

In Mr. Baracchi's paper were discussed the longitude values assigned to the two Australian meridians of Port Darwin and Southport (Queensland); these being, respectively, the terminals of the two chains of telegraphically determined longitudes carried eastward from Greenwich *via* India, Singapore, and

Port Darwin, in one case, and westward through Canada and the Pacific Ocean to Southport (Queensland) in the other case.

It was also shown that the connection between these two meridians obtained by means of the measured longitudinal arcs Port Darwin-Melbourne, Melbourne-Sydney, and Sydney-Southport (Queensland) completes a whole longitude circuit round the Earth, with a closing error of less than a hundred feet.

The reality of such a small error was questioned, chiefly on the ground that larger discrepancies were found in the independent results of certain links which have been measured more than once.

It was pointed out that in order to render the whole of this important longitude circuit homogeneous and reliable a re-measurement should be made of the arcs Madras-Singapore, Singapore-Port Darwin, and Port Darwin-Southport (Queensland), adopting the highest refinements of modern practice and present instrumental means.

The object of the paper was to enlist the sympathy of the British Association in this matter, and to obtain its advice as to the most practical and efficient plan of carrying out the work.

TUESDAY, AUGUST 18.

Joint Meeting with Section B (Chemistry).

Discussion on the Structure of Atoms and Molecules.

Sir Ernest Rutherford (abstract of remarks) : In recent times there has been an accumulation of convincing evidence of the independent existence of the chemical atom. The atomic theory is no longer merely an hypothesis introduced to explain the laws of chemical combination; we are able to detect and count the individual atoms. We can determine the actual mass of an atom in various ways, and know its value with considerable accuracy. The idea that the atom is an electrical structure received a great impetus by the detection of the electron by J. J. Thomson; and, moreover, the Zeeman effect showed that all atoms must contain electrons. The atomic character of negative electricity is well established; we always find the negative electron, however produced, carrying a definite charge. We have, unfortunately, not the same certainty with regard to the behaviour of positive electricity, for it cannot be obtained except associated with a mass comparable with that of a hydrogen atom. In J. J. Thomson's model of the atom the positive electricity was supposed (for mathematical reasons) to be distributed throughout a large sphere with the negative corpuscles moving inside it. This hypothesis has played a useful part in indicating possible lines of advance; but it does not fit in with more recent discoveries, which point to a concentrated positive nucleus.

We have now two powerful methods that aid us in determining the inner structure of the atom—the scattering of high-speed particles in transit through matter, and the vibrations of the interior parts of the atom. In C. T. R. Wilson's photographs of the tracks of the α particles through a gas we notice many sudden bends in the paths. In order to account for these deflections I have found it necessary to believe that there is a concentrated nucleus in the atom (having a certain number of units of charge), in which the main part of the mass resides; outside this there are a corresponding number of electrons. The whole dimensions of the nucleus are very small indeed compared with the distance of the outer electrons. From the scattering experiments it appears that the law of force right up to the nucleus is the inverse square law; no other formula would give accordance with the observations. The radius of the nucleus is of the order 10^{-12} cm. in the case of gold, and for a lighter element it is smaller still. The approach of the α particle to the nucleus of the hydrogen atom when the latter is set into very swift motion is exceedingly close—a distance even less than the diameter of an electron. From this it is probable that the hydrogen nucleus is simply the positive electron with a large electrical mass due to the great concentration of the positive charge. Another

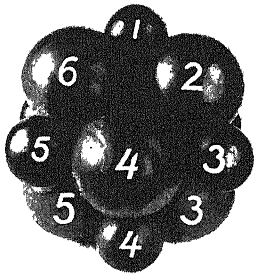
fact that appears from the scattering experiments is that the number of electrons (outside the nucleus) is about half the atomic weight. There is now fairly good evidence that, if the elements are numbered in order of atomic weight, the numbers will actually express the charge on the nucleus. The rate of vibration of the inner parts of the nucleus can now be measured by means of the characteristic X-rays emitted. Each substance has several strong lines in its X-ray spectrum, and as we pass from element to element in order of atomic weight the frequencies of these change by regular jumps. H. G. J. Moseley has investigated all the known elements in this way, and he is even able to show at what points elements are missing, because at such points the X-ray frequencies make a double jump. In this way he has found that between aluminium and gold only three elements are now missing. It is deduced from these considerations that there is something more fundamental in the atom than its atomic weight, viz., the charge on the nucleus, and that this is the main factor which controls the frequency of the interior vibrations, the mass having only a slight influence.

There are certain elements with identical chemical properties, but different atomic weights. Thus Radium-B (atomic weight 214) and lead (207) are chemically inseparable and have the same γ-ray spectrum. It is quite clear that some new conception is required to explain how the atoms, having the structure we have supposed, can hold together. N. Böhr has faced the difficulty by bringing in the idea of the quantum in a novel way. At all events, there is something going on in the atom which is inexplicable by the older mechanics.

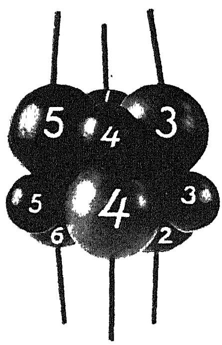
Professor ARMSTRONG: Although chemists must admire as well as welcome the bold attempt physicists are making to unravel the structure of the elementary atom, they cannot yet with advantage discuss the conclusions arrived at by their colleagues; the arguments used are so novel and daring, the contentions so original, that at present they are not in a position to appreciate, still less to criticise them effectively; in fact, the chemist's office at the moment must be mainly to point out the conditions that a theory must satisfy to meet his requirements. He has long been prepared to believe that the materials spoken of as elements may prove eventually to be compounds; indeed, the relationships between them are so similar to those manifest between carbon compounds, and of such a character, that it is almost necessary to believe in their composite nature; but the views that are now advocated by physicists are entirely different from any conceptions that chemists have ever entertained and cannot easily be assimilated by them. Physicists, unfortunately, in the past have held aloof from chemists; they have paid too little attention to their methods and to their results; the movement now in progress is therefore to be welcomed, as it must have the effect of leading the two parties in future to work together to a common end. Hence the value of the present discussion.

It is doubtful if it be permissible at present to conclude that elements of different atomic weight may and do exist which are indistinguishable chemically: the observations on which reliance is placed have been made with quantities of material far too small to permit of such an inference; in the case of the rare earth elements, although very large quantities of material have been at the disposal of chemists, they have only slowly discovered differences by which they are enabled to distinguish and separate them. Though the special methods made use of by physicists are very powerful, they suffice only in certain cases and have little chemical significance; when physicists resort to chemical methods the work becomes subject to ordinary criteria.

The resemblance of the X-ray spectra of so many elements is undoubtedly most significant, but to conclude, on such evidence, that all but very few of the elements are discovered is scarcely justifiable; it may well be that most of those that are known belong to a certain 'preferred' type and that a particular series is nearly complete, the similarity of the spectra being perhaps due to the presence of a radicle common to the series, much as in the case of a series of related benzenoid compounds. In the case of carbon compounds, of the large number of series possible, it is well known that certain types are formed preferentially, being more stable or more readily produced than others. If the so-called elements are compound substances, it may well be that the occurrence



Barlow-Pope Model of Benzene.



The same, showing arrangement of space affinities.

Illustrating Discussion on the Structure of Atoms and Molecules.

(From *Proc. Roy. Soc.*, 1914, Series A, Vol. 90, pp. 113, 146 ; by permission of the Royal Society.)

[*To face page* 295.

and prevalence of a certain type is determined in a somewhat similar way—that some one type has been preferred.

Any theory of atomic structure to be satisfactory to chemists must take fully into account the peculiar valency relationships that are manifest among the elements, as the system of 'structural' formulæ now in vogue is based solely upon these. The system is admittedly one of extraordinary perfection and remarkably simple. In the case of organic compounds, the rules laid down have been found to be applicable and to suffice in so many thousands upon thousands of cases that it is impossible to doubt their general correctness; at most it will be necessary eventually to translate them directly into some new language. It should be pointed out, however, that so-called structural formulæ are to be regarded as condensed symbolic expressions indicative of the general behaviour of the compounds represented in terms of certain well-understood conventions, rather than as actual representations of structure. For example, it is customary to represent benzene by a regular hexagon, a symbol which is a complete expression of the chemical behaviour of the hydrocarbon. But the six carbon atoms are not to be thought of as arranged in a plane and in a ring in the manner depicted by the symbol; such an arrangement is impossible if the affinities of the carbon atom act tetrahedrally. The structure of benzene is rather to be represented by a model in which six carbon atoms (represented by six large spheres) are arranged three and three, in two superposed layers, union taking place between an atom in one plane with a contiguous atom in the plane above, which in turn is united to that in the plane below—so that the atoms are connected in zigzag fashion; and the six hydrogen atoms are to be thought of as severally united to the six carbon atoms in such manner that the hydrogen atom is always in a plane different from that which contains the carbon atom with which it is connected. If the 'atoms' in such a model are squeezed down into one plane, the projection is practically identical with the ordinary 'centric' symbol of benzene. The arrangement referred to is shown in the accompanying figures (see Plate).

The fundamental assumption made by chemists, upon which their system of structural formulæ is based, is that the hydrogen atom has unit valency—that it is incapable of acting as a linking element. The whole of the evidence available appears to be in favour of this view. The contention advanced recently by Sir J. J. Thomson, that hydrogen may occur as a triatomic molecule, H_3, is therefore unacceptable; until the existence of such a molecule has been proved up to the hilt it will be impossible for chemists to admit its existence. The artifice by which Sir Joseph Thomson has sought to reconcile his interpretations with those of chemists practically involves the representation of hydrogen as a dyad; if this conclusion were accepted it would be necessary to double the valency of all other elements, a step which cannot be justified on chemical evidence. It is in cases such as these that a better understanding between chemists and physicists is required.

The variation of valency is probably the most perplexing phenomenon in chemistry. It is doubtful if any element have a higher 'true' or fundamental valency than carbon; the view sometimes put forward that certain elements may function even as octads is based on evidence which in no way justifies such an assumption. Not only will it be necessary to account for the variation in valency from element to element but also for the fluctuations observed especially in the case of the non-metallic elements. The variation seems to be determined by some reciprocal relationship between the interacting elements, valency apparently being a dependent variable rather than an absolute property; thus, to quote examples, whilst the hydrocarbon, CH_2, is non-existent and cannot exist *per se*, the corresponding oxide, carbonic oxide, CO, is not only stable but relatively inert, combining with other substances only under special conditions; and the corresponding sulphur compound is so active that it cannot exist independently, but at once undergoes polymerisation with explosive violence. Yet sulphuretted hydrogen occurs as a gas of simple molecular composition, whilst water, being a liquid of relatively high boiling-point, is presumably of considerable molecular complexity, so that it must be supposed that the fundamental molecule OH_2 is a highly active material. No theory of

atomic structure will be acceptable unless it can account for variations such as these.

Besides considering variations in atomic properties such as have been referred to, it will be necessary also, in devising a theory of atomic structure, to take into account the fact that valency is a 'directed function.' The tetrahedron apparently is a complete embodiment of the properties of the carbon atom, in so far as these are due to directed forces, if the affinities of the atom be thought of as proceeding from the centre of mass to the four apices. Or if, instead of representing carbon by a sphere four times the volume of the unit sphere representing the hydrogen atom, four unit spheres be piled in tetrahedral form, the four hollows into which other similar spheres will fit are in positions representing the directions in which affinity acts. The great body of facts arrived at by studying optically active 'asymmetric' carbon compounds are all compatible with such modes of representing carbon; moreover, the hypothesis is the only one devised that sets the necessary limit to the number of isomerides possible. What is true of carbon is true apparently of other elements. But it is very noteworthy that the affinity of carbon atoms for carbon atoms, as well as for those of many other elements, is extraordinarily strong in comparison with that of other elements for each other; carbon has properties which are altogether peculiar.

Fresh significance has been given to the problems of valency of late years owing to the introduction, by Barlow and Pope, of the conception that it is to be regarded as a function of the volume occupied by the atom. Assuming that the atoms are closely packed, they have succeeded to an extent which is altogether remarkable, by means of this hypothesis, in correlating crystalline form with molecular structure. Regarding the sphere within which the influence of the hydrogen atom is exercised as unity, that of the dyad elements is twice, that of the triad three times, that of a tetrad element such as carbon four times, as great as that of the hydrogen atom. The halogens appear to occupy the same relative volume as hydrogen. A large body of evidence to this effect is to be found in a recent communication to the Royal Society ('Proc. R. Soc.' A, vol. 90, p. 111, 1914). Apparently, when an element such as an atom of halogen is introduced in place of hydrogen, the alteration in volume which attends the change is not simply due to the displacement effected by the new atom: the alteration in composition involves alterations in the spheres of influence of all the atoms in the molecule, so that their relative volumes remain the same though their actual volumes may vary.

It is to be expected that many of the problems of molecular structure which in the past could not be considered, especially in the case of inorganic compounds, will now be amenable to treatment from the crystallographic side. The view originally put forward by Lavoisier and elaborated by Berzelius, that acids such as sulphuric acid are compounds of an acid oxide with 'water,' may be referred to as a case in point (see 'Proc. R. Soc.' A, vol. 90, p. 73, 1914).

In view of the production of helium in so many cases of 'atomic' disruption, it must not be forgotten that the problems of 'elementary' atomic structure still require study on the chemical side. It is not to be supposed that they are no longer amenable to chemical treatment and that they are ripe for purely physical treatment.

Professor Hicks: Professor Rutherford has approached the question chiefly from the side of radioactive phenomena, whilst Professor Armstrong has dealt with certain stereographic properties of the molecule which physicists must take account of in forming any theory of the structure of the atom itself. I propose to draw attention to certain aspects of the problem when approached from the spectroscopic side, *i.e.*, from consideration of the atom as a configuration capable of emitting definite sets of free vibrations. Before doing so, however, I should like to offer some criticism with reference to a point raised by Professor Rutherford, viz., the actual value of the effective nuclear charge in any case. Moseley's law indicates that they are consecutive multiples for the consecutive elements in the periodic table, and they are known if that for one, say He, is known. What evidence we have seems to me rather to weigh in favour of He having an atomic number 4 in place of 2 which is assumed by Rutherford, Böhr, and Moseley himself. That it is at least 2 is clear from

the double charge on the α particle, but it does not follow when two of the movable electrons are freed that nine are left bound with the nucleus. The supposition that the atomic number for H is 1 and for He is 2, means that there are no intermediate elements between them. But there are several considerations which point to the existence of 2. (1) Nicholson has given very weighty reasons for supposing that the lines observed in the corona and in nebulæ are due to two elements whose atomic weights lie between those of H and He, which he has called respectively Coronium and Nebulium. Their nuclear charges, however, are 4 and 5, which would make He 6. (2) Rydberg has proposed a theory of the constitution of the periodic table which has been remarkably justified in one respect by Moseley's measurements, in so far that it requires 32 elements between Kr and Ra-Em in place of 36 as hitherto supposed. The same reason which requires these 32 elements also requires 2 between H and He. (3) In the July number of the 'Philosophical Magazine' Rydberg has discussed Moseley's measurements of the frequencies of the Barkla K and L series, and finds that if N—the atomic number—be based on 4 for He, the frequencies of the lines can be represented by the following scheme :—

$K(\alpha)$ and $K(\beta)$	by	$P(N-3)^2$	$P(N-3{\cdot}5)^2$
$L(\alpha)$ and $L(\beta)$	,,	$P(N-3\times 3)^2$	$P(N-3\times 3{\cdot}5)^2$
$L(\gamma)$ and $L(\delta)$	,,	$P(N-4\times 3)^2$	$P(N-4\times 3{\cdot}5)^2$

but that such an arrangement is impossible if N be based on any other number than 4 for He. More exact numbers, however, are needed before these relations can be regarded as established.

We already know certain definite facts as to the constitution of an atom. They are :—

(1) All atoms contain electrons as a part of their constitution. Of these they can apparently lose a certain number without altering their chemical identity, whilst in the case of radioactive elements the loss of other sets changes them into different elements. We shall doubtless be justified in the assumption that the same law extends to all elements.

(2) There exist also positively charged nuclei associated with the atomic mass, containing multiples of the fundamental electric charge, and the evidence tends to show that the chemical nature of the element is determined by this multiple.

(3) In the case of a certain number of substances there are found associated magnetic doublets whose moments are multiples of a definite quantity, called by Weiss the magneton. It appears legitimate to suppose that the same phenomenon may exist in other elements, though whether the magneton has an independent existence or is a consequence of electronic motion is an open question. If the latter, an explanation of the multiple quality will have to be sought for.

Any theory of atomic structure must, then, be a theory of the way in which the atom is built up of these fundamental quantities. So far there are two types : (1) Thomson's theory of an extended positive nucleus within which the electrons revolve in Saturnian systems; (2) Rutherford's theory of an extremely small nucleus with electrons in planetary or Saturnian orbits. Neither of them, however, has shown the slightest aptitude in explaining the series laws of spectra. The actual structure must be a much more complicated one than is assumed in either. Unfortunately the complete mathematical treatment of the simplest case is one of extreme difficulty. We may, however, I believe, make one very important first step, viz., as to the direction in which to look for the source of the energy emitted in spectral radiations. This energy may arise either from small vibrations about a stable state or from change from one stable state to another. In both cases the stable states must be such as to lose no energy, and must therefore be in static equilibrium, or their relative motions must be such as to produce no change in an external field relative to itself—such as, for instance, a charged sphere moving with uniform velocity. In the first case the energy would be made up of extremely small amounts from all the atoms, and an increase in intensity would be due to increased ampli-

tudes. In the second case it is made up by relatively large amounts from a proportion only of the systems, and an increase would be due to a larger proportion of atoms changing from one system to another. In the first case, although the constancy of period follows as a matter of course, it is difficult to see how the conditions of Planck's quanta can be met, and that the ideas lying at the base of his theory are well founded there can be little doubt. In the second case the energy for each line is transferred in the same amount, and the constancy of the frequency follows at once from Planck's theory. These general considerations seem to point to the conclusion that the cause of spectral emission is change from one configuration to another of less internal energy. But there is experimental evidence pointing in the same direction. Stark has shown that the series lines in a spectrum are due to molecules which have lost one or more electrons. For instance, doublet series are due to molecules which have lost one electron, triplets two, &c., and we should therefore expect the energy emitted to be given out by their recombination to the neutral state. Since in general the larger proportion of spectral lines—both arc and spark—are either series or seem to be closely related to series lines, it would appear that change of state is one of the chief causes of radiation.

A further consideration pointing in the same direction is afforded by the fact that the formulæ to which series lines conform give the frequency itself, and not the square of the frequency, which latter is always the case when the forces of displacement are proportional to the displacements themselves. As Rayleigh has pointed out, the former case requires forces proportional to the velocities, and hence suggests motion in magnetic fields. Now we know these fields exist, and as a fact the only theory which reproduces Rydberg's formulæ is that of Ritz, depending only on magnetic fields. Unfortunately electrostatic fields exist and must be taken account of. If we could conceive of shells of constant magnetic force produced by electric charges moving in such a way that the electric forces between the moving charges themselves are annulled, we should have made a first step towards forming a basis of a satisfactory theory. That such motions are possible is rendered probable from consideration of Maxwell's classical case of two uniformly charged parallel plates moving parallel to one another with the velocity of light. The great desideratum in the present state of the question is, not attempts at forming a complete theory, but mathematical discussions of as many simple cases as possible, in order to obtain a clearer comprehension of what such systems may be expected to explain. From this point of view the recent most suggestive paper of Conway on 'An Electromagnetic Hypothesis as to the Origin of Series Spectra'[1] is of the greatest value. We want more of a similar nature.

Whilst, however, in all probability the greater portion of a spectrum is due to changes of configuration, it does not necessarily follow that lines related to the series are the only ones emitted. In fact, the high-frequency vibrations discovered by Barkla and measured quite recently by Moseley are clearly a case in point. Nicholson has determined recently the frequencies of small oscillation of electrons revolving round positively charged nuclei on the basis of the Rutherford theory. More especially he finds that the sets of lines observed in the corona and in nebulæ fit in very exactly for elements in which the nuclear charges are respectively 4 and 5, and the lines are due to neutral atoms and also to atoms which have lost or gained one or two or more electrons. The agreements are so close and so numerous as to leave little doubt of the general correctness of the theory. But the lines are certainly not connected in any way with the series type of line. Their appearance is probably due to the vast number of atoms in the corona and nebulæ in the line of sight all emitting vibrations, whilst the absence of the series type may be due to the rarefaction of the gas causing comparatively few changes from one configuration to another. Nicholson's theory stands alone as a first satisfactory theory of one type of spectra. Unfortunately this type contains so few examples that if they exist in other elements they have not been noticed. It affords considerable evidence that Rutherford's theory approximates to the actual case when the nuclear charge is a small multiple of the fundamental charge. Several attempts have

[1] *Phil. Mag.* xxvi. p. 1010, December 1913.

been made to apply Planck's theory of radiation to the explanation of the laws of spectra. The most ingenious and suggestive is that of Böhr. It is based on the Rutherford atom, but throws no further light on the structure of the atom itself, as the mechanism of radiation is totally unexplained, and it is this which we are in search of. The most remarkable result is the derivation of the value of Rydberg's constant from known electric constants, and Planck's constant. This result has certainly caught the scientific imagination, and one feels convinced, especially on a first reading of his paper, that there is some truth at the bottom of his theory. But Lindemann has pointed out, by consideration of dimensions, that a large number of theories would give values in which the various constants enter in the same way. In Böhr's theory the exactness of the numerical relation depends on an apparently arbitrary assumption as to the frequency of the energy emitted when an electron is combined. It is true that later he attempts to justify this by making his formula conform to certain observed properties of series. But with the introduction of this his value of Rydberg's constant ceases to be a direct deduction from his theory. Moreover, in doing so he assumes the frequency of an electron to be proportional to its angular velocity, which can only be the case for *one* electron—*i.e.*, for an atom built on a planetary system, and not on a Saturnian, as is his. Nicholson has recently criticised the theory on other grounds, and as he is to take part in the discussion I will leave this point to him. From the spectral point of view the weightiest objection would seem to be that it is capable only of giving a formula of the Balmer type—which holds for hydrogen alone. In the best-known series types, the P, S, and D depend on formulæ of the type $A - \frac{N}{(m+\mu)^2}$. The μ depend on atomic constants, and are always considerable for elements of large atomic weight. As the atomic weight diminishes we get the following general changes:—In P, μ decreases to 1; in D it increases to 1; in S it approaches the value ·5. In other words, for P and D the formulæ approach a Balmer type. For H it is indistinguishable from Balmer's. For He, though approaching Balmer's, it is decisively not 1. As a fact, Böhr's theory does not represent any of the six known series of He, but he postulates that certain lines hitherto allotted to H belong really to He. Moreover, he supposes He to have 2 electrons, whereas, as I have attempted to show above, the number is more probably 4. Fowler has recently presented a paper to the Royal Society in which he supports Böhr's allocation on observational grounds, but as it is not yet (August) published it is not possible to weigh the evidence. In concluding, I should like to say that although I have criticised certain parts of Böhr's theory adversely, no one can admire more its ingenuity and great suggestiveness.

Mr. H. G. J. Moseley explained the results of his classification of elements by their X-ray spectra. The frequency of the principal line in the X-ray spectrum is represented very closely by the formula

$$\gamma^{\frac{1}{2}} = K\ (N - B)$$

where K and B are constants, and N an integer increasing by a unit as we pass from element to element up the periodic table. If we take this atomic number N as ordinate, and the square root of the principal frequency as abscissa, the different elements will therefore give points lying approximately on a straight line. The secondary frequencies will at the same time give points on other straight lines. The order of the elements determined by N is nearly that of increasing atomic weight; there are one or two exceptions, and in such cases the order given by N, and not the atomic weight, is evidently the correct order corresponding to chemical properties. For example, the atomic weight gives the order Cl, K, A, whereas the X-ray frequency gives the order Cl, A, K. The latter is the order required by the periodic table. There are between aluminium and gold four missing elements, indicated by the double jump of N required to make the formula fit. These correspond generally to gaps indicated also by the periodic law.

Professor Nicholson: I prefer not to introduce new difficulties, which would only make the discussion too long, and will therefore confine my remarks to

those points on which my opinion has been invited by Professor Hicks. Firstly, with regard to Böhr's theory, such criticisms as I have made are in the main mathematical, and therefore unsuitable for a joint discussion between physicists and chemists. But I can give a statement of the present position of the theory as it appears to me. When Böhr's theory is applied to a single nucleus of strength e or $2e$, with a *single* rotating electron, it is remarkably successful in its deduction of the hydrogen series spectrum and of the Pickering series which it ascribes to helium. Its most striking success is, I think, not the very accurate deduction of the universal constant of spectra, but its application by Professor Fowler in his Bakerian lecture to a determination of the mass of an electron, on the supposition that the Pickering series comes from helium. The accuracy of this value cannot be ignored. But analysis shows that it is quite impossible to go further, and to derive the usual helium spectrum. I mean that in order to do so we must abandon at least one of Böhr's premises which is vital to the deduction of the hydrogen formula. This fact is capable of rigorous demonstration, as is also the fact that, under the inverse square law, which Sir Ernest Rutherford has shown experimentally to be valid, Rydberg's constant is not a feature of more complex atoms on this theory.

There is also an experimental difficulty. Whatever its origin, the Pickering series should be accompanied by an ultra-violet one in the Schumann region. This series has been found by Professor Lyman in the hydrogen spectrum, whereas helium appears to have no Schumann spectrum. Professor Lyman is repeating these experiments, in view of their importance, but the balance of experimental evidence is against Böhr's theory at present.

I am inclined to agree with Mr. Moseley that my nebular and coronal elements may not be chemical elements in the ordinary sense. This opinion, that they are sub-elements, or bases of ordinary elements, will be found in my papers. Bourget, Buisson, and Fabry's experiments, described in the 'Comptes Rendus,' show that these substances have the atomic weights which I calculated theoretically from their spectra, so that their existence appears to be real. Moreover, as in my papers, ordinary elements with series spectra can apparently only be formed from them by an alteration in the nucleus which does not affect its total charge. Evidence is accumulating to show that the nuclear structure may play an important part in series spectra, and therefore I am not inclined to agree with Professor Rutherford that the nucleus of a hydrogen atom is necessarily the positive electron. It seems to be more complicated. But with everything else in his admirable opening address I must express a general agreement. I must finally agree with Mr. Moseley that any ultimate atomic theory must involve Planck's h. In my own papers this was regarded as an angular momentum, as subsequently also by Böhr. The necessity for it is easily seen. For we only have one dynamical relation between the radius of the atom and the angular velocity of its electrons. Without the introduction of some new universal constant such as h no atom has anything in its nature which compels a definite size, and definite unchanging properties.

Professor H. Bassett said that, as the number of elements which came before neon seemed of considerable importance in connection with the theoretical treatment of the constitution of the atom, it might be worth while considering whether the periodic law gave any hints on the matter. It was well known that Lothar Meyer's atomic volume curve clearly demonstrated that, although the properties of the elements were periodic functions of their atomic weights, the periodicity was not of such a simple character as at first supposed by Newlands. Leaving out hydrogen for the moment, it was found that there were two short periods of eight elements each, beginning with neon and argon, and ending with fluorine and chlorine respectively, followed by two long periods of 18 elements—that was to say, of $(2\times8)+2$ elements. These two long periods were followed by one very much longer period and a portion of a second. Unfortunately this very long period was so far incompletely known, and it was not certain how many elements it contained; but this much could be said, namely, that it contained approximately twice as many elements as one of the long periods, and possibly 38 elements, which would be $(2\times18)+2$

elements. Now, going back to the region in which hydrogen was situated, one was tempted to suggest that this gas was the only known representative of an extra short period of three elements. Doubling this number and adding two one obtained eight—the number of elements in each of the known short periods. Doubling eight and adding two one obtained eighteen—the number of elements in each of the long periods, and so on. Although such treatment of the matter might appear like playing with figures, it seemed to the speaker of some interest.

Professor KERR GRANT summarised the difficulty as to the stability of a system consisting of one nucleus and one electron. It was difficult, too, to account for the non-magnetic character of the hydrogen atom with this structure. Magnetism, however, depended probably more on molecular than on atomic structure.

Sir E. RUTHERFORD (replying) said that the chemical inseparability of certain isotopes was, indeed, derived from experiments with small quantities, but the methods used were very delicate. The separation of Radium D from lead was a most important problem; there seems evidence that different leads exist, having different atomic weights. The difficulty of stability is common to all theories of the atom; but what it points to is that there is something wrong with the theory of electromagnetic radiation—not of the atom.

The following Paper was then read :—

On Salts coloured by Cathode Rays. By Professor E. GOLDSTEIN.
See Reports, p. 250.

The following Papers were read in Section A :—

1. *Note on the Magneton as a Scattering Agent of α and β Particles. By* Professor W. M. HICKS, *F.R.S.*

Weiss has proved the existence of elementary magnetic magnets—or their equivalent—as a constituent of the atoms of matter. These magnetons should act as very effective scatterers of α and β rays, but the mathematical difficulties of a complete discussion of the scattering by a single electron are probably extremely great. The particular case where the electrons move in an equatorial plane of the magneton admits, however, of a complete mathematical solution, and may be useful as throwing some light on the nature of the scattering to be expected. It is essentially a question of the orbits of charged particles coming from an infinite distance, and in the paper the nature and distribution of these are explained. Incidentally also a theory of combined electrons appears.

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2. *Demonstration of a Mechanical Analogue of Wireless Telegraphic Circuits. By* Professor T. R. LYLE, *F.R.S.*

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3. *On the Thermal Conductivity of Air. By* Professor T. H. LABY *and* E. O. HERENS.

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4. *The General Magnetic Survey of Australia. By* E. KIDSON.

WEDNESDAY, AUGUST 19.

Discussion on Antarctic Meteorology. Opened by G. C. SIMPSON, *D.Sc.*

1. A brief résumé was given of the general circulation in the atmosphere over the Southern Hemisphere as taught by:

(*a*) the text-books.

(*b*) Dr. Lockyer in his paper 'Southern Hemisphere Surface Air Circulation.'

(*c*) Professor Meinardus in his discussion of the result of the 'Gauss' Antarctic Expedition.

Dr. Lockyer suggests an intense anticyclone over the Antarctic Continent, from which cold air feeds into a series of large cyclones circulating the southern ocean and having their centres near to 60° S. The cyclones are supposed to be so large that while their southern extremities sweep over the edge of the Antarctic Continent their northern extremities reach to latitude 40° S., and so dominate the weather of Tasmania and New Zealand, and to some extent that of South Australia.

Professor Meinardus's scheme also includes a series of cyclones travelling from west to east over the southern ocean; but he gives strong reasons against the presence of an anticyclone over the southern continent. His chief objection to such an anticyclone is that anticyclonic conditions are accompanied by an excess of evaporation over precipitation; hence it would be impossible to account for the excess of precipitation which gives rise to the large glaciers and snow-fields which discharge the known large quantities of ice.

2. The simultaneous observations made at Cape Evans, Cape Adare, and Framheim were then considered to investigate the processes which are at work in the Ross Sea area. Diagrams showing the mean temperature distribution both horizontally and vertically were examined, and the curves of barometric pressure and wind at the different stations compared. The chief conclusions of the investigation are as follows: The high south-easterly winds—commonly called blizzards—are not caused by cyclones passing into the Ross Sea, but are the result of the large differences of temperature which exist in the lower atmosphere over the Barrier and the Ross Sea. The cloud observations show that air feeds into the Antarctic at high levels, and passes north again in the blizzards. Meinardus's objection that in such a circulation of air precipitation would not exceed the evaporation was shown not to hold, because of the great cooling of the air due to radiation. The air while sinking loses so much heat by radiation that, when forcibly made to rise in the blizzards, saturation is reached at a much lower level than that at which the air entered. Thus anticyclonic conditions are consistent with an excess of precipitation.

3. The existence of a belt of cyclones between the Antarctic Continent and Australia was then considered. Curves on which barometer and wind observations made at the 'Gauss' winter quarters are plotted were shown. From them it was seen that during the passage of deep waves of pressure there is practically no variation of the wind direction at that station. In most cases the wind blows a gale from the east both while the barometer falls rapidly and while it makes an equally rapid recovery. At present it appears quite impossible to reconcile the wind and barometer observations with any system of circulation of wind about a centre of low pressure moving from the west to the east. Further the simultaneous barometer observations at Melbourne, the Bluff (New Zealand), and Cape Adare were examined without finding any certain indication of the same cyclone affecting the northern and southern stations.

4. The monthly departures from normal of pressure at Cape Evans were compared with corresponding values for stations in Australasia, and an important negative correlation was found.

5. In conclusion the importance of a permanent meteorological station on the Antarctic Continent was urged.

The following Report and Papers were then read:—

1. *Report of the Seismological Committee.*—See Reports, p. 41.

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2. *On the Change of Thermal Conductivity during the Liquefaction of a Metal. By* Professor A. W. PORTER, *F.R.S., and* F. SIMEON.

3. *Experiments on the Active Deposit of Radium. By* E. WELLISCH.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *The Origin and Nature of the* γ *Rays from Radium. By* Professor Sir E. RUTHERFORD, *F.R.S.*

2. *The Distribution in Space of the Stars near the North Pole. By* Dr. F. W. DYSON, *F.R.S.*

3. *The Action of the Juice of* Euphorbia peplus *on a Photographic Plate. By* J. M. PETRIE *and* H. G. CHAPMAN.

The dried milky juice of *Euphorbia peplus* acts on a sensitive photographic plate in the dark. If a photographic plate, separated by a space of 3 mm., is exposed for fourteen days to the dried juice spread in the form of letters on glass, sharp images of the letters appear as positive impressions on the plate on development in the ordinary way. Faint images are formed by exposures for such short periods as twenty-four hours, and deeper impressions, but still sharp and well-defined, by exposures up to thirty-one days. The impressions on the plate are more marked when the separation is diminished to 1 mm., and no impression appears when the separation is increased to 12 mm. The images are characteristically well defined, though there is slight diffusion around each letter.

If a piece of black paper, impervious to light, be inserted between the letters and the plate, the images appear as well defined as when the paper is absent. The intervention of paraffined tissue paper fails to prevent the appearance of the image on the plate. Images are seen when thin aluminium foil and gold leaf are used to separate the plate from the letters. The impression can be obtained through thin sheet glass. When a strong current of air is passed between the letters and the plate during the exposure, the image appears sharp and no evidence of diffusion in the direction of the current can be made out.

On examining the dried juice with a sulphide screen no scintillation of particles can be seen. On testing the dried juice in a gold leaf electroscope there is no apparent increase in the rate of discharge of ionised gases. With a sensitive electrometer no action of the dried juice on ionised air could be detected.

On heating the dried juice, the photographic action is not diminished after several hours' heating to 200° C. When charred to a black mass the juice has a diminished action on the plate, and when incinerated to a white ash the ash retains a feeble action.

This photographic action has been noted with all specimens of *Euphorbia peplus* examined by us from many localities, some at least a hundred miles apart. The dried juice retains its action unchanged, so that the original sample, dried and mounted five years ago, is as active as ever.

The juices of many other species of Euphorbia, and of other plants with similar latex-bearing tubes, have no comparable action on the photographic plate.

4. *Photo-electric Effect in Selenium. By* Professor O. U. VONWILLER.

5. *The Pressure upon the Poles of a Carbon Arc.* *By* Professor W. G. DUFFIELD.

6. *The Attractions of Ellipsoidal Shells.* *By* Professor A. GRAY, *F.R.S.*

MONDAY, AUGUST 24.

The following Papers and Reports were read:—

1. *Discontinuities in Meteorological Phenomena.* *By* Professor H. H. TURNER, *F.R.S.*

2. *The Oblate Shape of the Stellar System.* *By* Professor A. S. EDDINGTON, *F.R.S.*

3. *An Absolute Determination of the Thermal Conductivity of Air.* *By* E. O. HERENS *and* T. H. LABY.

4. *The Nature of γ Rays.* *By* T. H. LABY *and* W. STUART.

5. *Length and Electrical Resistance of Steel Tapes.* *By* T. H. LABY *and* G. E. ADAMS.

6. *A Map of the Principal Earthquake Origins of the S.W. Pacific.* *By* G. HOGBEN.

7. *Report on the Investigation of the Upper Atmosphere.—See* Reports, p. 69.

8. *Report on the International Tables of Physical and Chemical Constants.*

9. *Report on the Calculation of Mathematical Tables.*—See Reports, p. 75.

10. *Report on the Disposal of Copies of the Binary Canon.*—See Reports, p. 102.

11. *Interim Report on Radiotelegraphic Investigations.*—See Reports, p. 70.

TUESDAY, AUGUST 25.

Joint Meeting with Section G (Engineering).

Discussion on Wireless Telegraphy. Opened by Sir OLIVER LODGE, *F.R.S.*

The following Papers were then read in Section A :—

1. *Some Measurements of the Wave-length in Air of Electrical Vibrations associated with a Thin Straight Terminated Rod.* *By* Professor J. A. POLLOCK.

2. *High-Frequency Spectra.* *By* H. G. J. MOSELEY.

3. *On the Scattering of Light by Small and Large Particles of Conducting and Non-conducting Substances.* *By* Professor ALFRED W. PORTER, *F.R.S., and* E. TALBOT PARIS, *B.Sc.*

The work summarised herein is a continuation of an investigation by Porter and Keen[1] on the diffraction of light by particles comparable with the wave-length. In that work the scattering was produced by a sulphur suspension, and observations were restricted to the transmitted light. In the present paper the degree of polarisation has been determined (by means of a double-image prism and nicol) for the light scattered in different directions; and suspensions of silver and copper have been investigated as well as suspensions of sulphur. The metallic suspensions were made by the method of Pieroni,[2] which we have found to give stable suspensions.

The results for sulphur particles show a good general agreement with the theoretical values calculated by Lord Rayleigh,[3] but exact comparison is not possible owing to the difficulty of determining the size of the particles. In the case of the silver particles comparison with theory is easier, because the total amount of silver present can be so readily determined chemically, the number of particles per unit volume can be counted, and thence their size can be calculated. Measurements of the size were also made by Perrin's method, i.e., by counting the number of particles in each of two layers a small vertical distance apart, and attributing the difference (as in an atmosphere of gas) to the total weight of particles in the intervening space. Both methods give practically the same results.

Complete curves have been obtained for the polarisation for different-sized particles in different directions. Mention will be made here only of the direction of maximum polarisation for silver suspensions for light of wave-length 550 $\mu\mu$. This is shown in the following table :—

Diameter of particles.	Direction of max. polarisation.	Relative electric conductivity.
$\mu\mu$		
80	90°	—
98	90°	2·96
108	98°·36′	3·70
131	109°·54′	4·12
164	113°·36′	—
310	130°·30′	—

[1] *Proc. Roy. Soc.* A, Vol. **89**, 1914.
[2] *Gazetta*, **43** (1), 197 (1913).
[3] *Proc. Roy. Soc.* A, Vol. **84**, 25 (1910).

According to J. J. Thomson,[4] the direction of maximum polarisation for perfectly conducting particles should make 120° with the incident light. From the above table it appears that for very small particles this angle is 90°, as it would be for *dielectric* particles (a fact which we find was previously observed by Professor R. Threlfall[5]), but that it increases as the diameter of the particle increases to a value above the theoretical limit.

Measurements were also made of the electrical conductivity of the suspensions. Since the average distance between the particles was about 100 times their diameter, Maxwell's theory of the conductivity of compound media is applicable. The conductivity was measured in every case for concentrations containing the same amount of silver and other bodies per unit volume, but differing only in the size of the particles. In these circumstances the conductances should be the same unless there is a difference in the conductivity of the silver particles. It will be seen that the conductivity of the mixture increases as the particles increase in size. It would seem, therefore, that the anomalous behaviour of the silver is due to a real change in resistance with size, and is not simply a consequence of the fact that Thomson's theory is limited to the cases for which the conductivity is sufficiently large.

No numerical calculation has previously been made for large particles. By transferring Thomson's equations so as to express the result in terms of the same functions which have been calculated by Lord Rayleigh for fairly large values of the argument, his work becomes available for the present problem; and one of us (E. T. P.) has calculated the degree of polarisation of the light scattered in different directions for perfectly conducting particles for which $\frac{2\pi \times \text{radius}}{\lambda}$ = unity, when λ = wave-length of the light. The maximum polarisation corresponds to an angle for about 108°. The value indicated by our experiments lies between 110° and 120°, but further experiments are necessary to fix it more exactly.

It is not difficult to suggest a reason for the diminution of the conductivity with size. Separated molecules, as in a vapour, are perfectly non-conducting; we conclude that there are then no free electrons. Aggregation of molecules of silver as in a solid gives rise to free electrons (and consequent conductivity) owing to the mutual action of the molecules upon one another. In small particles the number of free electrons may be proportionately less than for silver in mass.

It must not be forgotten, however, that a colloid particle in its medium is surrounded by a double layer consisting of polarised molecules of the medium, and it is quite possible that it is this polarised layer of a dielectric medium which modifies the optical properties of the silver.

4. *On the Viscosities of the Halogens in the Gaseous State.* *By* A. O. Rankine, *D.Sc.*

In this paper various methods which have been used for measuring the viscosities of the vapours of Chlorine, Bromine, and Iodine at a number of different temperatures were described.

The relations between the viscosities of these three gases were discussed. The laws are similar to those which the author has previously shown to apply to the group of inert gases.

Department of Mathematics.

1. *Symbolic Solution of Linear Partial Differential Equations of the Second Order.* *By* T. W. Chaundy, *M.A.*

Statement of Results.

Take equation in form $\frac{\delta^2 z}{\delta x \delta y} + \alpha\frac{\delta z}{\delta x} + \beta\frac{\delta z}{\delta y} + \gamma z = 0$, where α, β, γ denote functions of x, y. The invariants h, k are $\frac{\delta\alpha}{\delta x} + \alpha\beta - \gamma = h$, $\frac{\delta\beta}{\delta y} + \alpha\beta - \gamma = k$.

[4] *Recent Researches in Electricity and Magnetism*, p. 449. [5] *Phil. Mag.*, 1894.

Introduce symbolic operators $\Delta_y \equiv (-\int^x (k-h)dx\alpha + \frac{1}{\delta_x} h)$

$$\Delta_x \equiv (-\int^y (h-k)dy\beta + \frac{1}{\delta_y} k)$$

$$\Theta_y \equiv 1 + \frac{1}{\delta y}\Delta_y + \left(\frac{1}{\delta_y}\Delta_y\right)^2 + \ldots .$$

$$\Theta_x \equiv 1 + \frac{1}{\delta x}\Delta_x + \left(\frac{1}{\delta_x}\Delta_x\right)^2 + \ldots .$$

Then a symbolic solution appears as

$$e^{-\int^x \beta . dx} \Theta_y \phi(x) + e^{-\int^y \alpha . dy} \Theta_x \psi(y)$$

where ϕ, ψ are arbitrary functions of their arguments. Here the arbitrary elements enter in an infinite series of their derivative.

We may deduce a form of solution in which ϕ, ψ enter in finite terms, namely—

$$Z = e^{-\int^x \beta dx} \int^y \phi(t)\Theta_y \left[e^{t(\delta_y - \Delta_y)} 1\right]_{y=0} dt$$

$$+ e^{-\int^y \alpha . dx} \int^x \psi(t).\Theta_x \left[e^{t(\delta_x - \Delta_x)} 1\right]_{x=0} dt$$

Applying these results to the equation $S = z$ we obtain a solution

$$z = \int_o^y \phi(t).J\{(y-t)x\}\,dt + \int_o^x \psi(t).J\{(x-t)y\}\,dt + C.J(xy)$$

where C is a constant and $J(u) = 1 + \frac{u}{(1\,!)^2} + \frac{u^2}{(2\,!)^2} + \ldots \frac{u^n}{(n\,!)^2} + \ldots$

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2. *Properties of Algebraic Numbers Analogous to Certain Properties of Algebraic Functions.* *By* Professor J. C. Fields, *F.R.S.*

Suppose ϵ to be a root of an integral algebraic equation $f(x) = 0$ of degree n in x and irreducible in the domain of the rational numbers. Where p is a prime $f(x)$ may, however, happen to be reducible in the domain of the p-adic numbers. Assuming the number of the irreducible p-adic factors to be r we write $f(x) = f_1(x) \ldots f_r(x)$, where the coefficients of the powers of x in $f_1(x), \ldots f_r(x)$ are p-adic numbers.

Consider $R(\epsilon)$ any rational function of ϵ. It may be written as a polynomial of degree $n-1$ in ϵ and satisfies an algebraic equation $F(X) = 0$, where we have $F(X) = F_1(X) \ldots F_r(X)$. The factors $F_1(X), \ldots F_r(X)$ here have p-adic coefficients and are co-ordinated with the factors $f_1(x), \ldots f(x)$ of $f(x)$. The degrees of the factors $f_1(x), \ldots f_r(x)$, as also those of the factors $F_1(X), \ldots, F_r(X)$ will be certain integers $n_1, \ldots, n_r$ respectively. The constant terms in the factors $F_1(X), \ldots F_r(X)$ we name the *p-adic partial norms* of $R(\epsilon)$. The order numbers relative to p of the p-adic partial norms of $R(\epsilon)$ divided by $n_1, \ldots,$

n_r respectively we call the *orders of coincidence* of $R(\epsilon)$ with the p-adic factors of the fundamental equation $f(x) = 0$.

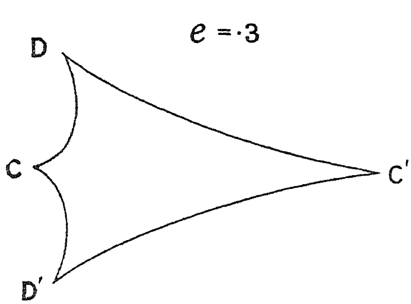
The coefficient of ϵ^{n-1} in the number $R(\epsilon)$ we call its *principal coefficient.* The orders of coincidence of such number relative to the prime p will be integral multiples of certain numbers $1/\nu_1, \ldots, 1/\nu_r$, where $\nu_1, \ldots, \nu_r$ are factors of $n_1, \ldots, n_r$ respectively. We consider the aggregate of numbers $R(\epsilon)$ possessing an assigned set of orders of coincidence relative to p. The necessary and sufficient condition that the principal coefficient in the aggregate be integral is that the assigned orders of coincidence have a certain set of values. This particular set of orders of coincidence defines *adjointness* relative to the prime p with regard to the fundamental equation.

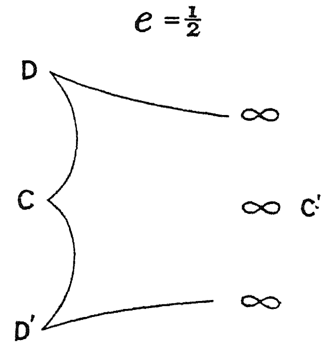
If we start out from a sufficiently general rational form $R(\epsilon)$ with its coefficients represented in p-adic form and impose on it the conditions requisite in order that it may possess a certain set of orders of coincidence relative to the prime p, these conditions take the form of a succession of independent congruences relative to the prime p imposed on the coefficients of the powers of p in the p-adic coefficients of the powers of ϵ. We find a formula for the number of these conditions. We also assign sets of orders of coincidence $\tau_1^{(p)}, \ldots \tau_{r_p}^{(p)}$ corresponding to all primes p, these orders of coincidence being 0 with the exception of a finite number among them. Such a system of orders of coincidence we call a *basis of coincidences.* We define *complementary adjoint bases of coincidences* and derive the analogue of the complementary theorem in the theory of the algebraic functions.

3. *The Green's Function for the Equation* $\nabla^2 u + k^2 u = 0$. *By* Professor H. S. Carslaw.

4. *The Evolute of the Limaçon.* *By* Professor W. H. H. Hudson, *M.A., LL.M.*

The equation of the Limaçon is taken in the form $r = a\,(1 + e\cos\theta)$, a will be made 1, and the abbreviations used $1 - e^2 = f$, $1 - 4e^2 = k$, $e\,(1+e)\,/\,(1+2e) = c$, $e\,(1-e)\,/\,(1-2e) = c'$.





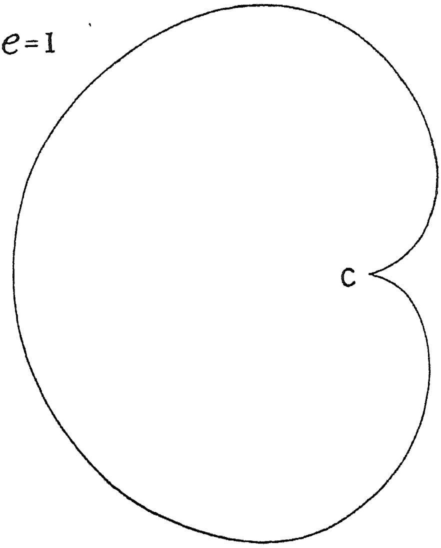
The Limaçon is symmetrical about the x-axis; so therefore is its evolute.

(1) When $e = 0$, the Limaçon is a circle; the evolute is a point, the centre of the circle.

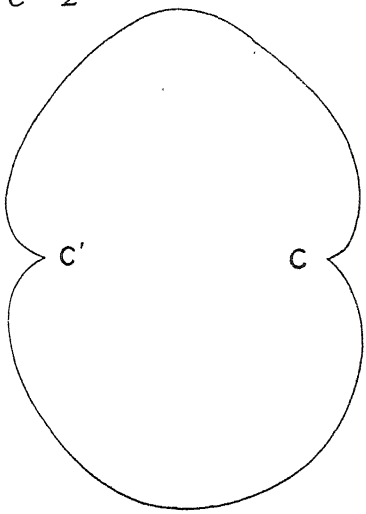
(2) When $\frac{1}{2} > e > 0$, the evolute is a closed curve with four cusps pointing outwards. These cusps are D, $(ef, e^2\sqrt{f})$, D'', $(ef, -e^2\sqrt{f})$, C, $(c, 0)$, C', $(c', 0)$. All four lie on the circle $y^2 + (x-c)(x-c') = 0$. As e increases, this at first star-like figure grows larger, the total height approaches $\sqrt{3}/4$ as e approaches $\frac{1}{2}$, the breadth (parallel to the x-axis) increases indefinitely.

(3) When $e = \frac{1}{2}$, c' becomes ∞, the height becomes $\sqrt{3}/4$. The cusp C' is at

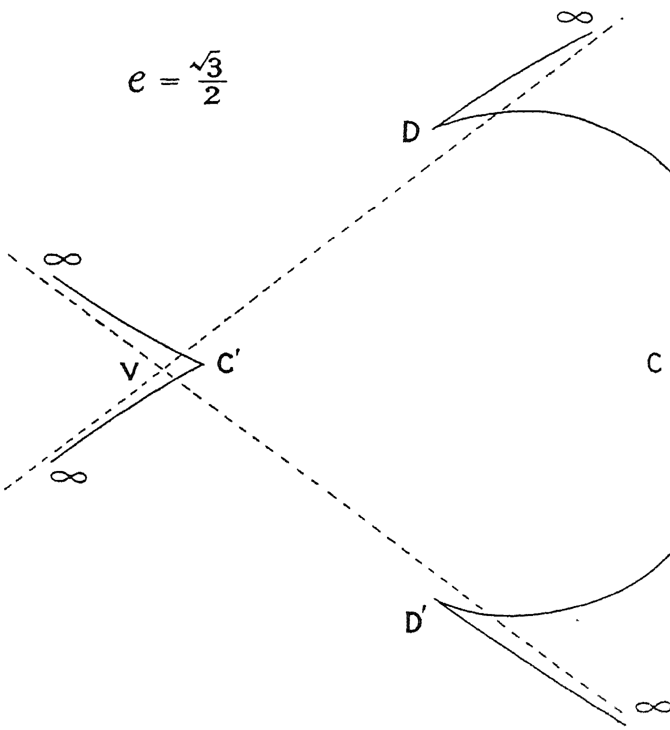
$e = 1$



$e = 2$



$e = \frac{\sqrt{3}}{2}$



infinity, the other three lie on the straight line $x = 3/8$, which may be regarded as a circle of infinite radius; the x- axis may be regarded as two coincident asymptotes.

(4) When $1 > e > \frac{1}{2}$, there are two asymptotes making equal angles with the x- axis. As e increases from $\frac{1}{2}$ to 1 the angle between the asymptotes increases from 0° to 180°, their intersection, V, moves from $(-\infty, 0)$ to the origin; the cusp C′ precedes V from $(-\infty, 0)$ to $(0, 0)$; the distance D D′ increases to a maximum $4\sqrt{3}/9$ when $e = \sqrt{(2/3)}$, and then dwindles to 0.

(5) When $e = 1$, the Limaçon is a cardioid, the evolute is also a cardioid; it passes through the origin, its cusp C is at $(2/3, 0)$; the three cusps C′, D, D′, coincident at the origin, become a simple point on the cardioid.

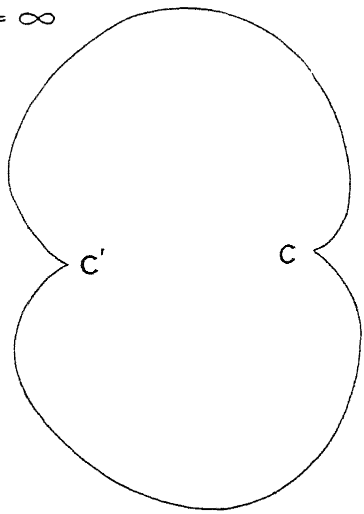
(6) When $e > 1$, the cusps D, D′ have disappeared, the cusps C, C′ point inwards, the curve is closed, the shape of the curve does not change much as e increases, the distance C C′ diminishes from 2/3 to $\frac{1}{2}$, the total height (parallel to the y- axis) increases from $\sqrt{3}/2$ to 1, the breadth, now less than the height, diminishes from 3/4 to $1/\sqrt{2}$.

(7) When $e = \infty$, the evolute is altogether at infinity; the difference $c - c'$ is found to be finite and equal to $\frac{1}{2}$, likewise the height, 1, the breadth, $1/\sqrt{2}$; the position of the breadth, $\frac{1}{4}/\sqrt{2}$, above and below C C′ enable an illustrative figure to be drawn. It is symmetrical about its central ordinate.

Diagrams are given to illustrate these cases, except (1), which needs no diagram.

(2) $e = \cdot 3$, the star elongated.
(3) $e = \frac{1}{2}$, with three cusps in a straight line.
(4) $e = \frac{1}{2}\sqrt{3}$, with the four cusps at the corners of a square.
(5) $e = 1$, where three cusps are hidden in one point.
(6) $e = 2$, the evolute of the Trisectrix.
(7) $e = \infty$, with double symmetry.

$e = \infty$



The equation of the evolute is

$$k^3 \left\{ y^2 + (x - c)(x - c') \right\}^3 + 27e^2y^2 (y^2 + x^2 - e\,a\,x)^2 = 0.$$

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5. *On the Algebraic Theory of Modular Systems (or Modules of Polynomials). By* F. S. Macaulay, *M.A.*

The theory of modules of polynomials is still only in its infancy, although it may claim an age of 135 years, its origin dating from the 'Théorie Générale des Equations Algébriques,' par M. Bézout, de l'Académie Royale des

Sciences, M.DCC.LXXIX. Its status and importance were made apparent by Kronecker's theory of Divisor Systems.

The central problem (of which no satisfactory solution has yet been given) is to find one or several ways of expressing the complete conditions that a polynomial F must satisfy in order that it may be capable of taking the form

$$F = X_1F_1 + X_2F_2 + \dots + X_kF_k,$$

where $F_1, F_2, \dots, F_k$ are given polynomials (in general non-homogeneous) in n variables $x_1, x_2, \dots, x_n$, and $X_1, X_2, \dots, X_k$ are any polynomials in the same variables, not given. The whole system of polynomials F is called a *module* (of polynomials), and is regarded as a single entity or class, and is symbolised by a letter M. Each F is called a *member* of M, and the set of polynomials $F_1, F_2, \dots, F_k$ is called a *basis* of M.

A module M is considered from its two conjugate aspects, viz. (i) its content as represented by its members, and (ii) its content as represented by its modular equations, *i.e.*, the linear equations which are identically satisfied by the coefficients of each and every member F of M. (ii) has received little attention hitherto. Either (i) or (ii) gives a complete representation of the module; but the difficulty is to obtain (ii) from (i) and *vice versa*. In combination (i) and (ii) give a very complete view of a module and afford together a simple answer to most general questions. Thus the members of the G.C.M. of any number of modules consist of all the members of all the modules; the modular equations of the L.C.M. of any number of modules consist of all the modular equations of all the modules; the members of the product MM′ of two modules M and M′ can be obtained at once from the members of M and M′; and the modular equations of a residual M/M′ can be obtained at once from the modular equations of M and the members of M′.

The most important types of modules were considered; these are the unmixed module, prime module (corresponding to a prime number in arithmetic), primary module (corresponding to a power of a prime in arithmetic), simple module (that is, a module containing one point only), module of the principal class, perfect module, and closed module. The method of obtaining the modular equations from a basis of the module was discussed, and also the resolution of a module into primary modules.

6. *A Theory of Double Points.* *By* F. S. MACAULAY, *M.A.*

BRISBANE.

FRIDAY, AUGUST 22.

Professor E. W. Brown, F.R.S., Vice-President of the Section, delivered the following Address :—

To one who has spent many years over the solution of a problem which is somewhat isolated from the more general questions of his subject, it is a satisfaction to have this opportunity for presenting the problem as a whole instead of in the piecemeal fashion which is necessary when there are many separate features to be worked out. In doing so, I shall try to avoid the more technical details of my subject as well as the temptation to enter into closely reasoned arguments, confining myself mainly to the results which have been obtained and to the conclusions which may be drawn from them.

In setting forth the present status of the problem, another side of it gives one a sense of pleasure. When a comparison between the work of the lunar theorist and that of the observer has to be made, it is necessary to take into consideration the facts and results obtained by astronomers for purposes not directly connected with the moon : the motions of the earth and planets, the position of the observer, the accuracy of star catalogues, the errors of the instruments used for the measurement of the places of celestial objects, the personality of the observers—

all these have to be considered; in fact, almost every one of the departments of the astronomy of position must be drawn upon to furnish necessary data. The time has now arrived when it may perhaps be possible to repay in some measure the debt thus contracted by furnishing to the astronomer, and perhaps also to the student of geodesy and, if I may coin a word, of selenodesy, some results which can be deduced more accurately from a study of the moon's motion than in any other way. A long-continued exploration with few companions which ultimately leads to territories where other workers have already blazed paths gives the impression of having emerged from the thick jungle into open country. The explorer can once more join forces with his brother astronomers. He can judge his own results more justly and have them judged by others. If, then, an excuse be needed for overstepping the limits which seem, by silent consent, to have been imposed on those who devote themselves to lunar problems, it consists in a desire to show that these limits are not necessary and that a study of the motion of the moon can be of value and can contribute its share to the common funds of astronomy.

The history of the motion of the moon has been for more than two centuries a struggle between the theorists and the observers. Ever since the publication of the 'Principia' and the enunciation of the law of gravitation by Isaac Newton, a constant effort has been maintained to prove that the moon, like the other bodies of the solar system, obeyed this law to its farthest consequences. While the theory was being advanced, the observers were continually improving their instruments and their methods of observing, with the additional advantage that their efforts had a cumulative effect: the longer the time covered by their observations, the more exact was the knowledge obtained. The theorist lacked the latter advantage: if he started anew he could only use the better instruments for analysis provided by the mathematician. He was always trying to forge a plate of armour which the observer with a gun whose power was increasing with the time could not penetrate. In the struggle the victory rarely failed to rest with the observer. Within the last decade we theorists have made another attempt to forge a new plate out of the old materials; whether we have substantially gained the victory must rest partly on the evidence I have to place before you to-day and partly on what the observer can produce in the near future.

There are three well-defined periods in the history of the subject as far as a complete development of the moon's motion is concerned. From the publication of the 'Principia' in 1687, when Newton laid down the broad outlines, until the middle of the eighteenth century, but little progress was made. It seems to have required over half-a-century for analysis by symbols to advance sufficiently far for extensive applications to the problems of celestial mechanics. Clairaut and d'Alembert both succeeded in rescuing the problem from the geometrical form into which Newton had cast it and in reducing it to analysis by the methods of the calculus. They were followed by Leonard Euler, who in my opinion is the greatest of all the successors of Isaac Newton as a lunar theorist. He initiated practically every method which has been used since his time, and his criticisms show that he had a good insight into their relative advantages. A long roll of names follows in this period. It was closed by the publication of the theories of Delaunay and Hansen and the tables of the latter, shortly after the middle of the nineteenth century. From then to the end of the century the published memoirs deal with special parts of the theory or with its more general aspects, but no complete development appeared which could supersede the results of Hansen.

My own theory, which was completed a few years ago, is rather the fulfilment to the utmost of the ideas of others than a new mode of finding the moon's motion. Its object was severely practical—to find in the most accurate way and by the shortest path the complete effect of the law of gravitation applied to the moon. It is a development of Hill's classic memoir of 1877. Hill in his turn was indebted to some extent to Euler. His indebtedness would have been greater had he been aware of a little-known paper of the latter, 'Sur la Variation de la Lune,' in which the orbit, now called the variation orbit, is obtained, and its advantages set forth in the words: 'Quelque chimérique cette question j'ose assurer que, si l'on réussissoit à en trouver une solution parfaite on ne trouveroit presque plus de difficulté pour déterminer le vrai mouvement de la Lune réelle.

Cette question est donc de la dernière importance et il sera toujours bon d'en approfondir toutes les difficultés, avant qu'on en puisse espérer une solution complète.'

In the final results of my work the development aims to include the gravitational action of every particle of matter which can have a sensible effect on the moon's motion, so that any differences which appear between theory and observation may not be set down to want of accuracy in the completeness with which the theory is carried out. Every known force capable of calculation is included.

So much for the theory. Gravitation, however, is only a law of force: we need the initial position, speed, and direction of motion. To get this with sufficient accuracy no single set of observations will serve; the new theory must be compared with as great a number of these as possible. To do this directly from the theory is far too long a task, and, moreover, it is not necessary. In the past every observation has been compared with the place shown in the 'Nautical Almanac' and the small differences between them have been recorded from day to day. By taking many of these differences and reducing them so as to correspond with differences at one date, the position of the moon at that date can be found with far greater accuracy than could be obtained through any one observation. At the Greenwich Observatory the moon has been observed and recorded regularly since 1750. With some 120 observations a year, there are about 20,000 available for comparison, quite apart from shorter series at other observatories. Unfortunately these observations are compared with incorrect theories, and, in the early days, the observers were not able to find out, with the accuracy required to-day, the errors of their instruments or the places of the stars with which the moon was compared. But we have means of correcting the observations, so that they can be freed from many of the errors present in the results which were published at the time the observations were made. We can also correct the older theories. They can be compared with the new theory and the differences calculated: these differences need not even be applied to the separate observations, but only to the observations combined into properly chosen groups. Thus the labour involved in making use of the earlier observations is much less than might appear at first sight.

For the past eighteen months I have been engaged in this work of finding the differences between the old theories and my own, as well as in correcting those observations which were made at times before the resources of the astronomer had reached their present stage of perfection. I have not dealt with the observations from the start: other workers, notably Airy in the last century and Cowell in this, have done the greater part of the labour. My share was mainly to carry theirs a stage further by adopting the latest theory and the best modern practice for the reduction of the observations. In this way a much closer agreement between theory and observation has been obtained, and the initial position and velocity of the moon at a given date are now known with an accuracy comparable with that of the theory. I shall shortly return to this problem and exhibit this degree of accuracy by means of some diagrams which will be thrown on the screen.

I have spoken of the determination of these initial values as if it constituted a problem separate from the theory. Theoretically it is so, but practically the two must go together. The increase in accuracy of the theory has gone on successively with increase in accuracy of the determination of these constants. We do not find, with a new theory, the new constants from the start, but corrections to the previously adopted values of these constants. In fact, all the problems of which I am talking are so much inter-related that it is only justifiable to separate them for the purposes of exposition.

Let us suppose that the theory and these constants have been found in numerical form, so that the position of the moon is shown by means of expressions which contain nothing unknown but the time. To find the moon's place at any date we have then only to insert that date and to perform the necessary numerical calculations. This is not done directly, on account of the labour involved. What are known as 'Tables of the Moon's Motion' are formed. These tables constitute an intermediate step between the theory and the positions of the moon which are printed in the 'Nautical Almanac.' Their sole use and necessity is the abbreviation of the work of calculation

required to predict the moon's place from the theoretical values which have been found. For this reason, the problem of producing efficient tables is not properly scientific: it is mainly economic. Nevertheless, I have found it as interesting and absorbing as any problem which involves masses of calculation is to those who are naturally fond of dealing with arithmetical work. My chief assistant, Mr. H. B. Hedrick, has employed his valuable experience in helping me to devise new ways of arranging the tables and making them simple for use.

A table is mainly a device by which calculations which are continually recurring are performed once for all time, so that those who need to make such calculations can read off the results from the table. In the case of the moon, the tables go in pairs. Each term in the moon's motion depends on an angle, and this angle depends on the date. One table gives the value of the angle at any date (a very little calculation enables the computer to find this), and the second table gives the value of the term for that angle. As the same angles are continually recurring, the second table will serve for all time.

We can, however, do better than construct one table for each term. The same angle can be made to serve for several terms and consequently one table may be constructed so as to include all of them. In other words, instead of looking out five numbers for five separate terms, the computer looks out one number which gives him the sum of the five terms. The more terms we can put into a single table the less work for the astronomer who wants the place of the moon, and therefore the more efficient the tables. A still better device is a single table which depends on two angles, known as a double-entry table; many more terms can usually be included in this than in a single-entry table. The double interpolation on each such table is avoided by having one angle the same for many double-entry tables and interpolating for that angle on the sum of the numbers extracted from the tables.

The problem of fitting the terms into the smallest number of tables is a problem in combinations—something like a mixture of a game at chess and a picture-puzzle, but unlike the latter in the fact that the intention is to produce ease and simplicity instead of difficulty. This work of arrangement is now completed and, in fact, about five-sixths of the calculations necessary to form the tables are done; over one-third of the copy is ready for the printer, but, owing to the large mass of the matter, it will take from two to three years to put it through the press. The cost of performing the calculations and printing the work has been met from a fund specially set aside for the purpose by Yale University.

A few statistics will perhaps give an idea of our work. Hansen has 300 terms in his three co-ordinates, and these are so grouped that about a hundred tables are used in finding a complete place of the moon. We have included over 1,000 terms in about 120 tables, so that there are on the average about eight terms per table. [In one of our tables we have been able to include no less than forty terms.] Each table is made as extensive as possible in order that the interpolations—the bane of all such calculations—shall be easy. The great majority of them involve multiplications by numbers less than 100. There are less than ten tables which will involve multiplications by numbers between 100 and 1,000 and none greater than the latter number. The computer who is set to work to find the longitude, latitude, and parallax of the moon will not need a table of logarithms from the beginning to the end of his work. The reason for this is that all multiplications by three figures or less can be done by Crelle's well-known tables or by a computing machine. But Mr. Hedrick has devised a table for interpolation to three places which is more rapid and easy than either of these aids. It is, of course, of use generally for all such calculations, and arrangements are now being made for the preparation and publication of his tables. The actual work of finding the place of the moon from the new lunar tables will, I believe, not take more time—perhaps less—than from Hansen's tables, as soon as the computer has made himself familiar with them. Fortunately for him, it is not necessary to understand the details of their construction: he need only know the rules for using them.

I am now going to show by means of some diagrams the deviations of the

moon from its theoretical orbit, in which, of course, errors of observation are included. The first two slides exhibit the average deviation of the moon from its computed place for the past century and a half in longitude.[1] The averages are taken over periods of 414 days and each point of the continuous line shows one such average. The dots are the results obtained by Newcomb from occultations; the averages for the first century are taken over periods of several years, and in the last sixty years over every year. In both cases the same theory and the same values of the constants have been used. Only one empirical term has been taken out—the long-period fluctuation found by Newcomb having a period of 270 years and a co-efficient of 13″. I shall show the deviations with this term included, in a moment.

The first point to which attention should be drawn is the agreement of the results deduced from the Greenwich meridian observations and those deduced from occultations gathered from observatories all over the world. There can be no doubt that the fluctuations are real and not due to errors of observation. A considerable difference appears about 1820, for which I have not been able to account, but I have reasons for thinking that the difference is mainly due to errors in the occultations rather than in the meridian values. In the last sixty years the differences become comparatively small, and the character of the deviation of the moon from its theoretical orbit is well marked. This deviation is obviously of a periodic character, but attempts to analyse it into one or two periodic terms have not met with success; the number of terms required for the purpose is too great to allow one to feel that they have a real existence, and that they would combine to represent the motion in the future. The straight line character of the deviations is a rather marked peculiarity of the curves.

The actual deviations on a smaller scale are shown in the next slide; the great empirical term has here been restored and is shown by a broken line. The continuous line represents the Greenwich meridian observations; the dots are Newcomb's results for the occultations before 1750, the date at which the meridian observations begin. With a very slight amount of smoothing, especially since 1850, this diagram may be considered to show the actual deviations of the moon from its theoretical orbit.

The next slide shows the average values of the eccentricity and of the position of the perigee.[2] The deviations are those from the values which I have obtained. It is obvious at once that there is little or nothing systematic about them; they may be put down almost entirely to errors of observation. The diminishing magnitude of the deviations as time goes on is good evidence for this; the accuracy of the observations has steadily increased. The coefficient of the term on which the eccentricity depends is found with a probable error of 0″·02, and the portion from 1750 to 1850 gives a value for it which agrees with that deduced from the portion 1850 to 1901 within 0″·01. The eccentricity is the constant which is now known with the highest degree of accuracy of any of those in the moon's motion. For the perigee there was a difference from the theoretical motion which would have caused the horizontal average in the curve to be tilted up one end over 2″ above that at the other end. I have taken this out, ascribing it to a wrong value for the earth's ellipticity; the point will be again referred to later. The actual value obtained from the observations themselves has been used in the diagram, so that the deviations shown are deviations from the observed value.

The next slide shows the deviations of the mean inclination and the motion of the node, as well as of the mean latitude from the values deduced from the observations.[3] In these cases the observations only run from 1847 to 1901. It did not seem worth while to extend them back to 1750 for it is evident that the errors are mainly accidental, and the mean results agreed so closely with those obtained by Newcomb from occultations that little would have been

[1] *Monthly Notices R.A.S.*, vol. 73, plate 22.

[2] Tables II., III. of a Paper on 'The Perigee and Eccentricity of the Moon,' *Monthly Notices R.A.S.*, March 1914.

[3] 'The Mean Latitudes of the Sun and Moon,' *Monthly Notices R.A.S.* Jan. 1914; 'The Determination of the Constants of the Node, the Inclination, the Earth's Ellipticity, and the Obliquity of the Ecliptic,' *ib.* June 1914.

gained by the use of the much less accurate observations made before 1847. The theoretical motion of the node differs from its observed value by a quantity which would have tilted up one end of the zero line about 0″·5 above the other; the hypothesis adopted in the case of the perigee will account for the difference.

The mean latitude curve is interesting. It should represent the mean deviations of the moon's centre from the ecliptic; but it actually represents the deviations from a plane 0″·5 below the ecliptic. A similar deviation was found by Newcomb. Certain periodic terms have also been taken out. The explanation of these terms will be referred to directly.

The net result of this work is a determination of the constants of eccentricity, inclination, and of the positions of the perigee and node with practical certainty. The motions of the perigee and node here agree with their theoretical values when the new value of the earth's ellipticity is used. The only outstanding parts requiring explanation are the deviations in the mean longitude. If inquiry is made as to the degree of accuracy which the usual statement of the gravitation law involves, it may be said that the index which the inverse square law contains does not differ from 2 by a fraction greater than 1/400,000,000. This is deduced from the agreement between the observed and theoretical motions of the perigee when we attribute the mean of the differences found for this motion and for that of the node to a defective value of the ellipticity of the earth.

I have mentioned the mean deviation of the latitude of the moon from the ecliptic. There are also periodic terms with the mean longitude as argument occurring both in the latitude and the longitude. My explanation of these was anticipated by Professor Bakhuysen by a few weeks. The term in longitude had been found from two series of Greenwich observations, one of 28 and the other of 21 years, by van Steenwijk, and Professor Bakhuysen, putting this with the deviations of the mean latitude found by Hansen and himself, attributed them to systematic irregularities of the moon's limbs.

What I have done is to find (1) the deviation of the mean latitude for 64 years, (2) a periodic term in latitude from observations covering 55 years, and (3) a periodic term in longitude from observations covering 150 years, the period being that of the mean longitude. Further, if to these be added Newcomb's deviations of the mean latitude derived (*a*) from immersions and (*b*) from emersions, we have a series of five separate determinations—separate because the occultations are derived from parts of the limb not wholly the same as those used in meridian observations. Now all these give a consistent shape to the moon's limb referred to its centre of mass. This shape agrees qualitatively with that which may be deduced from Franz's figure.

I throw on the screen two diagrammatic representations [4] of these irregularities obtained by Dr. F. Hayn from a long series of actual measures of the heights and depths of the lunar formations. The next slide shows the systematic character more clearly. It is from a paper by Franz.[5] It does not show the character of the heights and depths at the limb, but we may judge of these from the general character of the high and low areas of the portions which have been measured and which extend near to the limbs. I think there can be little doubt that this explanation of these small terms is correct, and if so it supplies a satisfactory cause for a number of puzzling inequalities.

The most interesting feature of this result is the general shape of the moon's limb relative to the centre of mass and its relation to the principle of isostasy. Here we see with some definiteness that the edge of the southern limb in general is further from the moon's centre of mass than the northern. Hence we must conclude that the density at least of the crust of the former is less than that of the latter, in accordance with the principle mentioned. The analogy to the figure of the earth with its marked land and sea hemispheres is perhaps worth pointing out, but the higher ground in the moon is mainly on the south of its equator, while that on the earth is north. Unfortunately we know nothing about the other face of the moon. Nevertheless it seems worth while to direct the attention of geologists to facts which may ultimately have some

[4] *Abh. der Math.-Phys. Kl. der Kön Sächs. Ges. der Wiss.*, vols. xxix., xxx.
[5] *Königsberger Astr. Beob.*, Abth. 38

cosmogonic applications. The astronomical difficulties are immediate: different corrections for meridian observations in latitude, in longitude, on Mösting A, for occultations and for the photographic method, will be required.

I next turn to a question, the chief interest of which is geodetic rather than astronomical. I have mentioned that a certain value of the earth's ellipticity will make the observed motions of the perigee and node agree with their theoretical values. This value is $1/293{\cdot}7 \pm {\cdot}3$. Now Helmert's value obtained from gravity determinations is $1/298{\cdot}3$. The conference of 'Nautical Almanac' Directors in 1911 adopted $1/297$. There is thus a considerable discrepancy. Other evidence, however, can be brought forward. Not long ago a series of simultaneous observations at the Cape and Greenwich Observatories was made in order to obtain a new value of the moon's parallax. After five years' work a hundred simultaneous pairs were obtained, the discussion of which give evidence of their excellence. Mr. Crommelin, of the Greenwich Observatory, who undertook this discussion, determined the ellipticity of the earth by a comparison between the theoretical and observed values of the parallax. He found an ellipticity $1/294{\cdot}4 \pm 1{\cdot}5$ closely agreeing with that which I have obtained. Finally, Col. Clarke's value obtained from geodetic measures was $1/293{\cdot}5$. We have thus three quite different determinations ranging round $1/294$ to set against a fourth determination of $1/298$. The term in the latitude of the moon which has often been used for this purpose is of little value on account of the coefficient being also dependent on the value of the obliquity of the ecliptic; such evidence as it presents is rather in favour of the larger value. I omit Hill's value, obtained from gravity determinations, because it is obviously too large.

Here, then, is a definite issue. To satisfy the observations of the moon in at least three different parts, a value near $1/294$ must be used; while the value most carefully found from gravity determinations is $1/298$. As far as astronomy is concerned, the moon is the only body for which a correct value of this constant is important, and it would seem inadvisable to use a value which will cause a disagreement between theory and observation in at least three different ways. It is a question whether the conference value should not be changed with the advent of the new lunar tables.

In looking forward to future determinations of this constant, it seems to be quite possible that direct observations of the moon's parallax are likely to furnish at least as accurate a value of the earth's shape as any other method. This can be done, I believe, much better by the Harvard photographic method than by meridian observations. Two identical instruments are advisable for the best results, one placed in the northern and the other in the southern hemisphere from 60° to 90° apart in latitude and as nearly as possible on the same meridian. On nights which are fine at both stations, from fifteen to twenty pairs of plates could be obtained. In a few months it is probable that some 400 pairs might be obtained. These should furnish a value for the parallax with a probable error of about $0''{\cdot}02$ and a value for the ellipticity within half a unit of the denominator 294. It would be still more interesting if the two instruments could be set up on meridians in different parts of the earth. The Cape and a northern observatory, Upsala for example, would furnish one arc; Harvard and Ariquipa or Santiago another. If it were possible to connect by triangulation Australia with the Asiatic continent, a third could be obtained near the meridian of Brisbane. Or, accepting the observed parallax and the earth's ellipticity, we could find by observation the lengths of long arcs on the earth's surface with high accuracy.

In any case, I believe that the time must shortly come when the photographic method of finding the moon's place should be taken up more extensively, whether it be used for the determination of the moon's parallax and the earth's ellipticity or not. The Greenwich meridian observations have been and continue to be a wonderful storehouse for long series of observations of the positions of the sun, moon, planets, and stars. In the United States, Harvard Observatory has adopted the plan of securing continuous photographic records of the sky with particular reference to photometric work. Under Professor Pickering it will also continue the photographic record of the moon's position as long as arrangements can be made to measure the plates and compute the moon's position from them.

In spite of the fact that Harvard Observatory has undertaken to continue for the present the work of photographing the moon's position, I believe that this method should find a permanent home in a national observatory. It has already shown itself capable of producing the accuracy which the best modern observations of Greenwich can furnish, and no higher praise need be given. If this home could be found in the southern hemisphere, and more particularly in Australia, other advantages would accrue.

But we should look for more than this. In an observatory whose first duty might be the securing of the best daily records of the sky, the positions of the sun, stars, planets, a couple of plates of the moon on every night when she is visible would be a small matter. What is needed is an organisation so constructed as to be out of the reach of changing governmental policy with a permanent appropriation and a staff of the highest character removed from all political influences. It could render immense service to astronomers, not only in the Empire but all over the world. The pride which every Englishman feels who has to work with the records of the past furnished by Greenwich would in course of time arise from the work of a similar establishment elsewhere. Those of us who live in a community which, reckoning by the age of nations, is new, know that, in order to achieve objects which are not material, sacrifices must be made; but we also know that such sacrifices are beneficial, not only in themselves, but as exerting an indirect influence in promoting the cause of higher education and of scientific progress in every direction. In saying this I am not advocating the cause of the few, but of the majority; the least practical investigations of yesterday are continually becoming of the greatest practical value to-day.

No address before this section is complete without some speculation and a glance towards the future. I shall indulge in both to some small extent before closing. I have shown you what the outstanding residuals in the moon's motion are: they consist mainly of long-period fluctuations in the mean longitude. I have not mentioned the secular changes because the evidence for them does not rest on modern observations but on ancient eclipses, and these are matters too debatable to discuss in the limited time allotted to me for this address. It may be said, however, that the only secular motion which is capable of being determined from the modern observations and is not affected by the discussion of ancient eclipses—namely, the secular motion of the perigee—agrees with its theoretical value well within the probable error. With this remark I pass to the empirical terms.

These unexplained differences between theory and observation may be separated into two parts. First, Newcomb's term of period between 250 and 300 years and coefficient 13″, and, second, the fluctuations which appear to have an approximate period of 60 to 70 years. The former appears to be more important than the latter, but from the investigator's point of view it is less so. The force depends on the degree of inclination of the curve to the zero line or on the curvature, according to the hypothesis made. In either case the shorter period term is much more striking, and, as I have pointed out on several occasions, it is much more likely to lead to the sources of these terms than the longer period. It is also, at least for the last sixty years, much better determined from observation, and is not likely to be confounded with unknown secular changes.

Various hypotheses have been advanced within the last few years to account for these terms. Some of them postulate matter not directly observed or matter with unknown constants; others, deviations of the Newtonian law from its exact expression; still others, non-gravitational forces. M. St. Blancat[6] examines a variety of cases of intramercurial planets and arrives at the conclusion that such matter, if it exists, must have a mass comparable with that of Mercury. Some time ago I examined the same hypothesis and arrived at similar results. The smallest planet with density four times that of water, which would produce the long inequality, must have a disc of nearly 2″ in its transit across the sun and a still larger planet would be necessary to produce the shorter period terms. But observational attempts, particularly those made by Perrine and Campbell, have always failed to detect any such planet, and Professor Campbell is of the opinion that a body with so large a disc could hardly have been overlooked. If

[6] *Annales de la Faculté des Sciences de Toulouse*, 1907.

we fall back on a swarm instead of a single body, we replace one difficulty by two. The light from such a swarm would be greater than that from a single body, and would therefore make detection more likely. If the swarm were more diffused we encounter the difficulty that it would not be held together by its own attraction, and would therefore soon scatter into a ring; such a ring cannot give periodic changes of the kind required.

The shading of gravitation by interposing matter, *e.g.* at the time of eclipses, has been examined by Bottlinger.[7] For one reason alone, I believe this is very doubtful. It is difficult to see how new periodicities can be produced; the periods should be combinations of those already present in the moon's motion. The sixty to seventy years' fluctuation stands out in this respect because its period is not anywhere near any period present in the moon's motion or any probable combination of the moon's periods. Indeed Dr. Bottlinger's curve shows this: there is no trace of the fluctuation.

Some four years ago I examined[8] a number of hypotheses. The motions of the magnetic field of the earth and of postulated fields on the moon had to be rejected, mainly because they caused impossible increases in the mean motion of the perigee. An equatorial ellipticity of the sun's mass, combined with a rotation period very nearly one month in length, appeared to be the best of these hypotheses. The obvious objections to it are, first, that such an ellipticity, small as it can be (about 1/20,000), is difficult to understand on physical grounds, and, second, that the rotation period of the nucleus which might be supposed to possess this elliptic shape in the sun's equator is a quantity which is so doubtful that it furnishes no help from observation, although the observed periods are well within the required limits. Dr. Hale's discovery of the magnetic field of the sun is of interest in this connection. Such a field, of non-uniform strength, and rotating with the sun, is mathematically exactly equivalent to an equatorial ellipticity of the sun's mass, so that the hypothesis might stand from the mathematical point of view, the expression of the symbols in words being alone different.

The last-published hypothesis is that of Professor Turner,[9] who assumes that the Leonids have finite mass and that a big swarm of them periodically disturbs the moon as the orbits of the earth and the swarm intersect. I had examined this myself last summer, but rejected it because, although it explained the straight line appearance of the curve of fluctuations, one of the most important of the changes of direction in this curve was not accounted for. We have the further difficulty that continual encounters with the earth will spread the swarm along its orbit, so that the swarm with this idea should be a late arrival and its periodic effect on the moon's motion of diminishing amplitude; with respect to the latter, the observed amplitude seems rather to have increased.

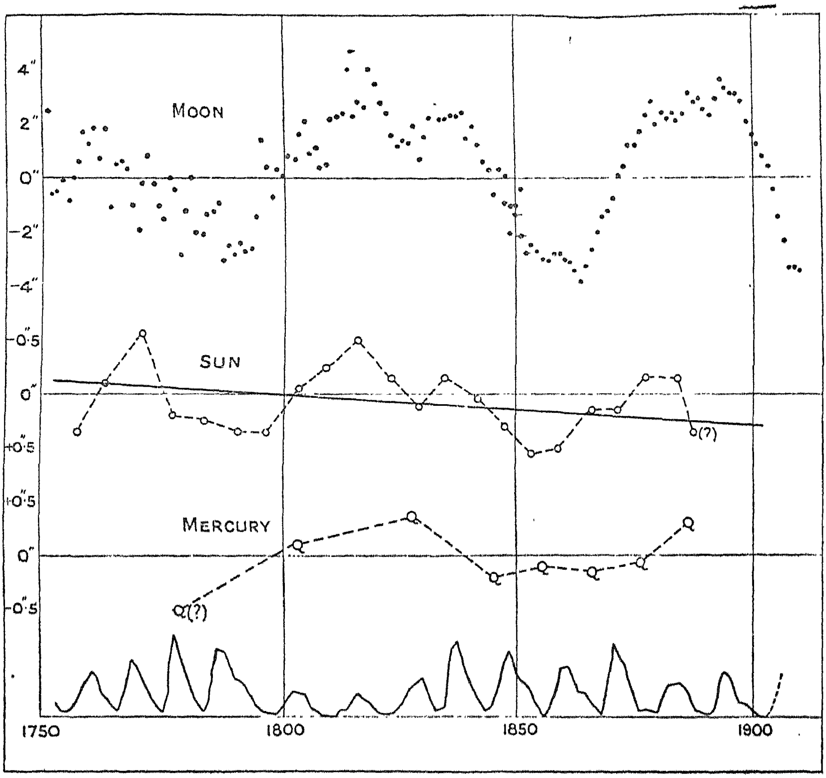
The main objection to all these ideas consists in the fact that they stand alone: there is as yet little or no collateral evidence from other sources. The difficulty, in fact, is not that of finding an hypothesis to fit the facts, but of selecting one out of many. The last hypothesis which I shall mention is one which is less definite than the others, but which does appear to have some other evidence in its favour.

The magnetic forces, mentioned above, were changes in the *directions* of assumed magnetic fields. If we assume changes in the intensities of the fields themselves, we avoid the difficulties of altering portions of the moon's motion other than that of the mean motion. We know that the earth's magnetic field varies and that the sun has such a field, and there is no inherent improbability in attributing similar fields to the moon and the planets. If we assume that variations in the strength of these fields arise in the sun and are communicated to the other bodies of the solar system, we should expect fluctuations having the same period and of the same or opposite phase but differing in magnitude. It therefore becomes of interest to search for fluctuations in the motions of the planets similar to that found in the moon's orbit. The material in available form for this purpose is rather scanty; it needs to be

[7] *Diss.*, Freiburg i. Br., 1912. [8] *Amer. Jour. Sc.*, vol. 29.
[9] *Monthly Notices*, December 1913.

a long series of observations reduced on a uniform plan. The best I know is in Newcomb's 'Astronomical Constants.' He gives there the material for the earth arranged in groups of a few years at a time. The results for Mercury, given for another purpose, can also be extracted from the same place. For Venus and Mars, Newcomb unfortunately only printed the normal equations from which he deduces the constants of the orbit.

On the screen is shown a slide (see below) which exhibits the results for the Earth and Mercury compared with those for the moon. In the uppermost curve are reproduced the minor fluctuations of the moon shown earlier; the second curve contains those of the earth's longitude; the third, those of Mercury's longitude. [By accident the mean motion correction has been left in the Earth curve; the zero line is therefore inclined instead of being



horizontal.] It will be noticed that the scales are different and that the Earth curve is reversed. In spite of the fact that the probable errors of the results in the second and third curves are not much less than their divergencies from a straight line, I think that the correlation exhibited is of some significance. If it is, we have here a force whose period, if period in the strict sense it has, is the same as that of the effect: the latter is not then a resonance from combination with another period. We must therefore look for some kind of a surge spreading through the solar system and affecting planets and satellites the same way but to different degrees.

The lowest curve is an old friend, that of Wolf's sunspot frequency, put there, not for that reason, but because the known connection for the last sixty years between sunspot frequency and prevalence of magnetic disturbance

enables us with fair probability to extend the latter back to 1750. With some change of phase the periods of high and low maxima correspond nearly with the fluctuations above. The eleven-year oscillation is naturally eliminated from the group results for the Earth and Mercury. One might expect it to be present in the lunar curve, but owing to its shorter period we should probably not obtain a coefficient of over half-a-second. Notwithstanding this fact, it is a valid objection to the hypothesis that there is no evidence of it in the moon's motion. Reasons may exist for this: but until the mechanism of the action can be made more definite it is hardly worth while to belabour the point.

The hypothesis presents many difficulties. Even if one is disposed to admit provisionally a correlation between the four curves—and this is open to considerable doubt—it is difficult to understand how, under the electron theory of magnetic storms, the motions of moon and planets can be sensibly affected. I am perhaps catching at straws in attempting to relate two such different phenomena with one another, but when we are in the presence of anomalies which show points of resemblance and which lack the property of analysis into strict periodic sequences some latitude may be permissible.

In conclusion, what, it may well be asked, is the future of the lunar theory now that the gravitational effects appear to have been considered in such detail that further numerical work in the theory is not likely to advance our knowledge very materially? What good purpose is to be served by continuous observation of the moon and comparison with the theory? I believe that the answer lies mainly in the investigation of the fluctuations already mentioned. I have not referred to other periodic terms which have been found because the observational evidence for their real existence rests on foundations much less secure. These need to be examined more carefully, and this examination must, I think, depend mainly on future observations rather than on the records of the past. Only by the greatest care in making the observations and in eliminating systematic and other errors from them can these matters be fully elucidated. If this can be achieved and if the new theory and tables serve, as they should, to eliminate all the known effects of gravitation, we shall be in a position to investigate with some confidence the other forces which seem to be at work in the solar system and at which we can now only guess. Assistance should be afforded by observations of the sun and planets, but the moon is nearest to us and is, chiefly on that account, the best instrument for their detection. Doubtless other investigations will arise in the future. But the solution of the known problems is still to be sought, and the laying of the coping stone on the edifice reared through the last two centuries cannot be a simple matter. Even our abler successors will hardly exclaim, with Hotspur,

> 'By heaven, methinks, it were an easy leap
> To pluck bright honour from the pale-faced moon.'

They, like us and our predecessors, must go through long and careful investigations to find out the new truths before they have solved our difficulties, and in their turn they will discover new problems to solve for those who follow them:—

'For the fortune of us, that are the moon's men, doth ebb and flow like the sea, being governed, as the sea is, by the moon.'

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION.—Professor WILLIAM J. POPE, M.A., LL.D., F.R.S.

MELBOURNE.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

THE British Association has been firmly established as one of the institutions of our Empire for more than half a century past. The powerful hold which it has acquired probably arises from the welcome which every worker in science extends to an occasional cessation of his ordinary routine—a respite during which the details of the specific inquiry in hand may be temporarily cast aside, and replaced by leisurely discussion with colleagues on the broader issues of scientific progress.

The investigator, continually occupied with his own problems and faced with an ever-increasing mass of technical literature, ordinarily finds little time for reflection upon the real meaning of his work; he secures, in general, far too few opportunities of considering in a philosophical sort of way the past, present, and future of his own particular branch of scientific activity. It is not difficult to form a fairly accurate survey of the position to which Chemistry had attained a generation ago, perhaps even a few years ago; probably no intellect at present existing could pronounce judgment upon the present position of our science in terms which would commend themselves to the historian of the twenty-first century. Doubtless even one equipped with a complete knowledge of all that has been achieved, standing on the very frontier of scientific advance and peering into the surrounding darkness, would be quite incompetent to make any adequate forecast of the conquests which will be made by chemical and physical science during the next fifty years. At the same time, chemical history tells us that progress is the result in large measure of imperfect attempts to appreciate the present and to forecast the future. I therefore propose to lay before you a sketch of the present position of certain branches of chemical knowledge and to discuss the directions in which progress is to be sought; none of us dare cherish the conviction that his views on such matters are correct, but everyone desirous of contributing towards the development of his science must attempt an appreciation of this kind. The importance to the worker and to the subject of free ventilation and discussion of the point of view taken by the individual can scarcely be over-estimated.

The two sciences of Chemistry and Physics were at one time included as parts of the larger subject entitled Natural Philosophy, but in the early part of the nineteenth century they drew apart. Under the stimulus of Dalton's atomic theory, Chemistry developed into a study of the interior of the molecule, and, as a result of the complication of the observed phenomena, progressed from stage to stage as a closely reasoned mass of observed facts and logical conclusions. Physics, less entangled in its infancy with numbers of experimental data which apparently did not admit of quantitative correlation, was developed largely as a branch of applied mathematics; such achievements of the formal

Physics of the last century as the mathematical theory of light and the kinetic theory of gases are monuments to the powers of the human intellect.

The path of Chemistry, as an application of pure logical argument to the interpretation of complex masses of observations, thus gradually diverged from that taken by Physics as the mathematical treatment of less involved experimental data, although both subjects derived their impetus to development from the speculations of genius.

It is interesting to note, however, that during recent years the two sciences, which were so sharply distinguished twenty years ago as to lead to mutual misunderstandings, are now converging. Many purely chemical questions have received such full quantitative study that the results are susceptible to attack by the methods of the mathematical physicist; on the other hand, the intense complication perceived during the fuller examination of many physical problems has led to their interpretation by the logical argument of the chemist because the traditional mathematical mode of attack of the physicist has proved powerless to deal with the intricacies exhibited by the observed facts.

The progress of Chemistry during the last century has been mainly the result of the co-ordination of observed facts in accordance with a series of hypotheses each closely related in point of time to the one preceding it. The atomic theory, as it was enunciated by Dalton in 1803, was a great impetus to chemical investigation, but proved insufficient to embrace all the known facts; it was supplemented in 1813 by Avogadro's theorem—that equal volumes of gases contain the same numbers of molecules at the same temperature and pressure. These two important theoretical developments led to the association of a definite physical meaning with the idea of molecular *composition*, but ultimately proved insufficient for the interpretation of the ever-increasing mass of chemical knowledge collected under their stimulus. A further great impetus followed the introduction by Frankland and Kekulé, in 1852 onwards, of the idea of valency and the mode of building up constitutional formulæ; the conception of molecular *constitution* thus arose as a refinement on the Daltonian notion of molecular composition. In course of time the theoretical scheme once more proved insufficient to accommodate the accumulated facts, until, in 1874, van 't Hoff and Le Bel demonstrated the all-important part which molecular *configuration* plays in the interpretation of certain classes of phenomena known to the organic Chemist.

During the early days of chemical science—those of Dalton's time and perhaps also those of Frankland and Kekulé—we can believe that chemical theory may have lacked the physical reality which it now seems to us to present; the attitude of our predecessors towards the theoretical interpretation of their observations was rather that described by Plato: 'as when men in a dark cavern judge of external objects by the shadows which they cast into the cavern.' In the writings of the most clear-sighted of our forerunners we can detect an underlying suspicion of a possibility that, at some time or other, the theory by means of which chemical observations are held together may undergo an entire reconstruction; a very few years ago Ostwald made a determined attempt to treat our science without the aid of the molecular hypothesis, and indeed suggested the desirability of giving the Daltonian atomic theory decent burial.

The last ten years or so has seen a change in this attitude. The development of Organic Chemistry has revealed so complete a correspondence between the indications of the conception of molecular constitution and configuration and the observed facts, and recent work on the existence of the molecule, largely in connection with colloids, with radioactivity, and with crystal structure, is so free from ambiguity, that persistence of doubt seems unreasonable. Probably most chemists are prepared to regard the present doctrine of chemical constitution and configuration as proven; although they may turn a dim vision towards the next great development, they have few misgivings as to the stability of the position which has already been attained.

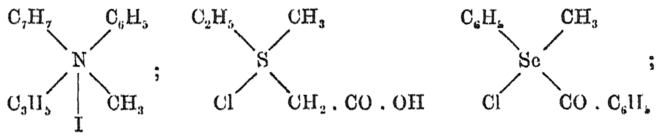
Let us consider how far the study of Organic Chemistry has hitherto led us; we may pass over the gigantic achievements of those who in past generations determined constitution and performed syntheses, thus making the subject one of the most perfect examples of scientific classification which exist, and turn

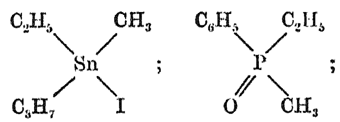
to the question of molecular configuration. In 1815 Biot observed that certain liquid organic substances deflect the plane of polarisation of a transmitted ray of light either to the right or to the left; half-a-century later Pasteur and Paternò pointed the obvious conclusion, namely, that the right- or left-handed deviation thus exerted must be due to a corresponding right- or left-handedness in the configuration of the chemical molecule. A scheme representing such right- or left-handedness, or enantiomorphism, was first enunciated by van 't Hoff and Le Bel upon the basis of the previously established doctrine of chemical constitution; briefly stated, the idea suggested was that the methane molecule, CH_4, was not to be regarded as extended in a plane in the manner represented by the Frankland-Kekulé constitutional formula, but as built up symmetrically in three-dimensional space. The carbon atom of the methane molecule thus occupies the centre of a regular tetrahedron, of which the apices are replaced by the four hydrogen atoms. A methane derivative, in which one carbon is separately attached to four different univalent atoms or radicles of the type CXYZW, should thus exist in two enantiomorphous configurations, one exhibiting right- and the other left-handedness. The inventors of this daringly mechanistic interpretation of the far less concrete constitutional formulæ were able to interpret immediately a large number of known facts, previously incomprehensible, by means of their extension of the Frankland-Kekulé view of constitution. They showed that every substance then known, which in the liquid state exhibited so-called optical activity, could be regarded as a derivative of methane in which the methane carbon atom was attached to four different univalent atoms or groups of atoms; a methane carbon atom so associated is termed an asymmetric carbon atom. It is of interest to note that the van 't Hoff-Le Bel deduction resulted from the discussion of the behaviour of organic substances of some molecular complexity; the optically active substances then known were mostly the products of animal or vegetable life, and among them none occurs which contains less than three carbon atoms in the molecule. Lactic acid, $CH_3 . CH(OH) . CO . OH$, is practically the most simple optically active substance of natural occurrence; it contains twelve atoms in the molecule, and it has only recently been found possible to associate optical activity with a much more simply constituted substance, namely, chloriodomethanesulphonic acid $CHClI . SO_3H$, the molecule of which contains less than 5 per cent. of carbon and only nine atoms, four more than the minimum number, five, which theoretically can give rise to optical activity.[1]

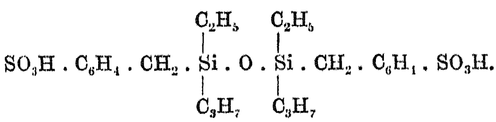
The working out of the practical consequences of the doctrine of the tetrahedral configuration of the methane carbon atom by von Baeyer, Emil Fischer, and Wislicenus is now a matter of history; the acquisition of masses of experimental data, broad in principle and minute in detail, placed the van 't Hoff-Le Bel hypothesis beyond dispute. The rapid growth of Organic Chemistry as a classified subject contrasted strongly with that of Inorganic Chemistry, in which the collection of a great variety of detailed knowledge incapable of far-reaching logical correlation formed the most striking feature; in fact, the extension of the conclusion, proven in the case of carbon compounds, that the Frankland-Kekulé constitutional formulæ must be translated into terms of three-dimensional space, to compounds of elements other than carbon, did not immediately follow the application of the theory to this element. Twenty years ago, indeed, the idea prevailed that carbon compounds differed radically from those of other elements, and we were not prepared to transfer theoretical conclusions from the organic to the inorganic side of our subject. In 1891, however, Le Bel stated that he had found optical activity associated with asymmetry of a quinquevalent nitrogen atom; although the experimental work upon which this conclusion was founded is now known to be incorrect,[2] the conception thus put forward was important, as suggesting that the notion of space-configuration could not be restricted logically to methane derivatives. When it was proved in 1899 that benzylphenylallylmethylammonium iodide could exist in a right- and left-handed configuration, it became necessary to admit that the spacial arrangement of the parts of a chemical molecule, previously restricted to methane derivatives, must be extended to ammonium salts.[3]

[1] Pope and Read, *Trans. Chem. Soc.*, 1914, **105**, 811. [2] *Ibid.*, 1912, **101**, 519.
[3] Pope and Peachey, *Trans. Chem. Soc.*, 1899, **75**, 1127.

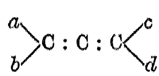
The demonstration that optical activity, or enantiomorphism, of molecular configuration is associated not only with the presence of an asymmetric quadrivalent carbon atom, but also with that of a nitrogen atom attached to five different radicles, was the result of an improvement of technique in connection with the study of optical activity; previously the resolution into optically active components of a potentially optically active basic substance had been attempted with the aid of naturally occurring optically active weak acids of the general type of *d*-tartaric acid. The application of the strong *d*- and *l*-bromocamphorsulphonic acids and the *d*- and *l*-camphorsulphonic acids to such purposes rendered possible the isolation of the optically active substances containing no asymmetric atom other than one of quinquevalent nitrogen. The resolution of asymmetric quaternary ammonium salts of the kind indicated was rapidly followed by the preparation of optically active substances in which the enantiomorphism is associated with the presence of an asymmetric sulphur, selenium, tin, phosphorus, or silicon atom; compounds of the following constitutions were thus obtained in optically active modifications :—



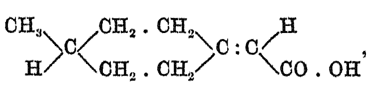




In all this work, and amongst all the varied classes of optically active compounds prepared, it was in every instance possible to indicate one particular quadrivalent or quinquevalent atom in the molecule which is separately attached to four or five different atoms or radicles; the enantiomorphism of molecular configuration may be detected, in fact, by the observation that such an asymmetric atom is present. It must, however, be insisted that the observed optical activity is the result of the enantiomorphism of the molecular configuration; the asymmetry of a particular atom is not to be regarded as the cause of the optical activity but merely as a convenient geometrical sign of molecular enantiomorphism. In 1874 van 't Hoff realised that molecular enantiomorphism and optical activity might conceivably exist without the presence of an asymmetric carbon atom, and suggested that compounds of the type



should be of this kind. Previously this particular case had escaped realisation experimentally, but an example fulfilling similar conditions was described in 1909; in this year the *d*- and *l*-isomerides of 1-methylcyclohexylidene-4-acetic acid,



were obtained.[4] The consideration of the constitution of these substances shows

[4] Perkin, Pope, and Wallach, *Trans. Chem. Soc.*, 1909, **95**, 1789; Perkin and Pope, *Trans. Chem. Soc.*, 1911, **99**, 1510.

no carbon atom which is attached to four different groups, but a study of the solid model representing the molecular configuration built up in accordance with the van 't Hoff-Wislicenus conclusions reveals the enantiomorphism.

It is of some importance to note that the configurations assigned to such optically active substances as have been mentioned above, on the basis of the experimental evidence, are of as symmetrical a character as the conditions permit; the Kekulé formula for methane, CH_4, in which all five atoms lie in the same plane, is not of so highly symmetrical a character as the van 't Hoff-Le Bel configuration in which the four hydrogen atoms are situate at the apices of a regular tetrahedron described about the carbon atom as centre. Some influence seems to be operative which tends to distribute the component radicles in an unsymmetrical molecule in as symmetrical a manner as possible; recent work indicates, however, that this is not always true. During the past few years Mills and Bain [5] have shown that the synthetic substance of the constitution

$$\begin{matrix} CH_3 \\ H \end{matrix} > C < \begin{matrix} CH_2 . CH_2 \\ CH_2 . CH_2 \end{matrix} > C : N . OH$$

can be resolved into optically active modifications. The conclusion is thus forced upon us that the trivalent nitrogen atom in such compounds is not environed in the most symmetrical manner possible by the surrounding components of the molecule; the experimental verification which the conclusions of Hantzsch and Werner, concerning the isomerism of the oximes, thus derive, constitutes the first really direct evidence justifying their acceptance.

Quite recently, and by the application largely of the optically active powerful sulphonic acids derived from camphor, Werner has made another great advance in connection with the subject of optical activity. He has obtained a number of complex compounds of chromium, cobalt, iron, and rhodium in optically active modifications.

The foregoing brief statement probably suffices to indicate the progress which has been made during the last twenty years in demonstrating that the atoms or radicles associated in the chemical molecule do not lie in one plane but are disposed about certain constituent atoms in three-dimensional space; careful study of the present stage of progress shows that we must attribute to molecular configuration, as determined by modern chemical methods, a very real significance. It can no longer be supposed to possess the purely diagrammatic character which attached to the Frankland-Kekulé constitutional formulæ; it seems to be proved that the men who developed the doctrine of valency were not merely pursuing an empirical mode of classification, capable of various modes of physical interpretation, but were devising the main scheme of a correct mechanical model of the chemical universe.

The development of a branch of science such as that now under discussion is, to a considerable extent, an artistic pursuit; it calls for the exercise of manipulative skill, of a knowledge of materials, and of originality of conception, which probably originate in intuition and empiricism, but must be applied with scientific acumen and logical judgment. For reasons of this kind many gaps occur in our present knowledge of the subject; although so many important conclusions find an unshakable foundation on facts relating to optical activity, we have as yet no clear idea as to why substances of enantiomorphous molecular configuration exhibit optical activity. Great masses of quantitative data referring to optical activity have been accumulated; something has been done towards their correlation by Armstrong, Frankland, Pickard, Lowry, and others, but we still await from the mathematical physicist a theory of optical activity comparable in quantitative completeness to the electro-magnetic theory of light. Until we get such a theory it seems unlikely that much further progress will be made in interpreting quantitative determinations of rotation constants.

That aspect of stereochemistry which has just been so briefly reviewed represents a situation which has been attained during the natural development

[5] *Trans. Chem. Soc.*, 1910, 97, 1866.

of Organic Chemistry by methods which have now become traditional; progress has been made by the application of strictly logical methods of interpretation to masses of experimental data, and each new conclusion has been checked and verified by the accumulation of fresh contributions in the laboratory. The sureness of the methods adopted could not fail to lead to the intrusion of stereochemistry into adjacent fields of scientific activity; bio-chemistry, the study of the chemical processes occurring in living organisms, is already largely dominated by stereochemistry, and the certainty with which stereochemistry has inspired us as to the reality of the molecular constitution of matter is exerting a powerful influence in other branches of natural science. Quite possibly, however, the acquaintance which every chemist possesses of the great progress already made upon one particular set of lines is to some extent an obstacle to his appreciation of new directions in which further great stereochemical advances may be anticipated.

A little reflection will show that the study of the relation between the crystalline form and chemical constitution or configuration of substances in general may confidently be expected to lead to important extensions of our knowledge of the manner in which the atoms are arranged in molecular complexes. The earlier crystallographic work of the nineteenth century led to the conclusion that each substance affects some particular crystalline form, that the regular external crystalline shape is an expression of the internal structure of the crystal, and that a determination of the simpler properties—geometrical, optical, and the like—of a crystalline material constitutes a mode of completely characterising the substance. Later work during the last century demonstrated that the properties of crystalline substances are in entire harmony with a simple assumption as to the manner in which the units or particles of the material are arranged; the assumption is that the arrangement is a geometrically 'homogeneous' one, namely, an arrangement in which similar units are uniformly repeated throughout the structure, corresponding points presenting everywhere a similar environment. The assumption of homogeneity of structure imposes a definite limitation upon the kinds of arrangement which are possible in crystals; it leads to the inquiry as to how many types of homogeneous arrangement of points in space are possible, and to the identification of these types with the known classes of crystal symmetry. The final conclusion has been attained that there are 230 geometrically homogeneous modes of distributing units, or points representing material particles, throughout space; these, the so-called 230 homogeneous 'point-systems,' fall into the thirty-two types of symmetry exhibited by crystalline solids. The solution of the purely geometrical problem here involved was commenced by Frankenheim in 1830, and finally completed by Barlow in 1894; it brings us face to face with the much larger stereochemical problem—that of determining what the units are which become homogeneously arranged in the crystal, why they become so arranged, and in what way a connection can be established between chemical constitution and crystal structure.

Since the conception of homogeneity of structure alone is clearly insufficient for the interpretation of the more advanced problem, some further assumption must be made as a foundation for any really comprehensive attempt to collate the quantities of isolated facts bearing upon the subject. Of the many assumptions which have been made in this connection only one, which may now be stated, has as yet proved fruitful in the sense that it serves to correlate large numbers of known experimental facts, and that it indicates the way to the discovery of fresh facts. The assumption is that each atom in a crystalline structure acts as a centre of operation of two opposing forces: (*a*) a repellent force, attributable to the kinetic energy of the atom, and (*b*) an attractive force, both forces, like gravity, being governed by some inverse distance law. Such an assumption forms an essential part of the classical work of Clerk Maxwell and van der Waals on the kinetic theory of gases and liquids. Its application to solid crystalline substances, where it must be applied in conjunction with the principle of structural homogeneity, was made by Barlow and myself in 1906.

The operation of the assumption just stated is readily visualised by considering the simplest possible case, that, namely, of a crystalline element each

molecule of which consists of but one atom and in which all the atoms are similar. Consideration of this kind of case shows that the set of identically similar centres of attracting and opposing forces will be in equilibrium when one particular simple condition is fulfilled; the condition is that, with a given density of packing of the centres, the distance separating nearest centres is a maximum. Two homogeneous arrangements of points fulfil this condition, and these exhibit the symmetry of the cubic and the hexagonal crystalline systems.

Since the nature of the two arrangements of points is not easily realised by mere inspection, the systems must be presented in some alternative form for the purpose of more clearly demonstrating their properties; this is done conveniently by imagining each point in either arrangement to swell as a sphere until contact is made with the neighbouring points. The two arrangements then become those shown in Figs. 1 and 2, and are distinguished as the cubic and the hexagonal closest-packed assemblages of equal spheres; they differ from all other homogeneous arrangements in presenting maximum closeness of packing of the component spheres. The equilibrium condition previously remarked - that, with a given density of distribution of the force centres in space, the distance separating nearest centres is a maximum—is revealed in the assemblages of spheres as the condition that the spheres are arranged with the maximum closeness of packing.

A further step is yet necessary. Each point in the arrangements considered is regarded as the mean centre of an atom of the crystalline element, but the assumption originally made states nothing about the magnitude of the atom itself; it is therefore convenient to regard the whole of the available space as filled by the atoms, without interstices. This is conveniently done by imagining tangent planes drawn at each contact of sphere with sphere, so partitioning the available space into plane-sided polyhedra, each of which may be described as the domain of one component atom. The twelve-sided polyhedra thus derived from the cubic and the hexagonal assemblages represent the solid areas throughout which each atom exercises a predominant influence in establishing the equilibrium arrangement.

The two assemblages can now be described in a quantitative manner by stating the symmetry and also the relative dimensions of each. The cubic assemblage exhibits symmetry identical with that of the cube or the regular octahedron, a symmetry characteristic of so-called holohedral cubic crystals; the relative dimensions in different directions are defined by the symmetry. The assemblage can, in fact, be referred to three axes parallel to the edges of a cube, and as these directions are obviously similar in a cube, their ratios are of the form, $a : b : c = 1 : 1 : 1$. This expression indicates that if the assemblage, supposed indefinitely extended through space, is moved by a unit distance in either of the three rectangular directions a, b, and c, the effect, as examined from any point, is as if the assemblage had not been moved at all.

The symmetry of the hexagonal assemblage is identical with that of a hexagonal prism or of a double hexagonal pyramid, and is that characteristic of the so-called holohedral, hexagonal, crystalline system; the relative dimensions are no longer defined entirely by the symmetry, and are conveniently stated as the ratio of the diameter, a, of the prism or pyramid, to the height, c, of the pyramid. The ratio, $a : c$, for the assemblage of spheres under discussion can be calculated; it assumes two forms, corresponding to two modes of selecting alternative principal diameters of the prism as unit. The alternative ratios are:

$$a : c = 1 : 1{\cdot}6330 \text{ or } a : c = 1 : 1{\cdot}4142.$$

This somewhat lengthy theoretical discussion has now reached a stage at which it can be applied to the observed facts; the accompanying table (Table I.) states the mode in which crystalline substances of different degrees of molecular complexity distribute themselves amongst the various crystal systems. Of the elements which have been crystallographically examined, 50 per cent. are cubic, whilst a further 35 per cent. are hexagonal: and consideration of the data for these latter shows that they exhibit approximately the axial ratios characteristic of the hexagonal closest-packed assemblage; thus magnesium shows $a : c = 1 : 1{\cdot}6242$, and arsenic the ratio $a : c = 1 : 1{\cdot}4025$.

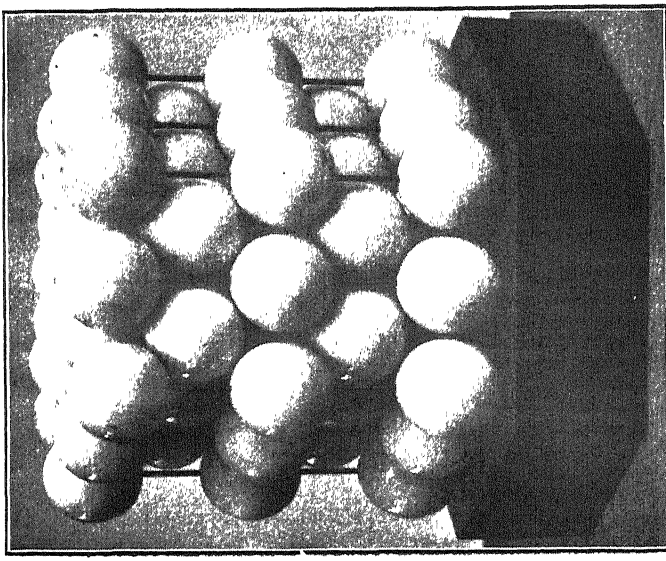


FIG. 2.

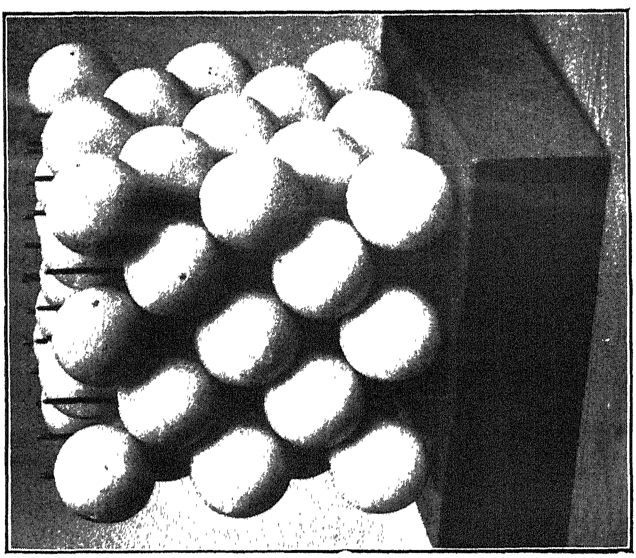


FIG. 1.

Illustrating Professor William J. Pope's Address to the Chemistry Section.

[*To face page* 328

TABLE I.

System		Inorganic Substances, the Number of Atoms in the Molecule of which is respectively: Elements					Organic Substances
	Per cent.	2	3	4	5	More than 5	
Cubic	50	68·5	42	5	12	5·8	2·5
Hexagonal	35	19·5	11	35	38	14·6	4·0
Tetragonal	5	4·5	19	5	6	7	5·0
Orthorhombic	5	3·0	23·5	50	36	27·3	34·0
Monosymmetric	5	4·5	3	5	6	37·3	47·5
Anorthic	0	0	1·5	0	2	8	7·0
Number of cases examined for each vertical column	140	67	63	20	50	673	585

Whilst the crystal structure of some 85 per cent. of the crystalline elements seems to be in general agreement with the simple assumption of equilibrium which has been made, the divergence presented by about 15 per cent. of the elements still awaits explanation. The previous discussion applies to the theoretically simple case of a monoatomic element; many of the elements are, however, certainly polyatomic. Imagine, therefore, that in the crystal structure, agreeing with the cubic or hexagonal arrangement just described, the similar atoms are grouped to form complex molecules, each containing two or more atoms; the geometrical effect of this grouping, if any, should be, first, to degrade the symmetry of the structure, and, secondly, to slightly alter its relative dimensions. It would therefore be expected that if the elements which are neither cubic nor hexagonal owe their departure from those systems to molecular aggregation, the crystal dimensions should approximate closely to those of the two ideal assemblages; this is, indeed, found to be the case. Monosymmetric sulphur, for instance, exhibits the axial ratios, $a : b : c = 0·9958 : 1 : 0·9988$, $\beta = 95° 46'$; the relative dimensions in the three directions, a, b, and c, are almost the same as in the cubic system, and the angle between the directions a and c is $\beta = 95° 46'$, instead of $90°$. This substance has nearly the dimensions of a cubic crystal, and is obviously 'pseudo-cubic'; the same is true of all other elements which depart from true cubic or hexagonal symmetry.

The crystalline forms presented by the elements are consequently in accordance with the assumption that the crystal structures are equilibrium arrangements of the component atoms of the two kinds described. It is also indicated that aggregation of the atoms to form molecular complexes is responsible for the departure from simple cubic or hexagonal symmetry; in this connection it is interesting to note that the strongly coloured elements depart most widely from these two systems. Thus, the colourless modifications of carbon and phosphorus are cubic, whilst the black graphite is monosymmetric and the red phosphorus is orthorhombic in crystal form; this is in accordance with the general view that colour is the result of some particular kind of molecular aggregation.

Although so much general correspondence of a quantitative character is to be observed between the observed facts and the anticipations developed from the equilibrium assumption, it has become evident during the last year or two that the conception formed as to the nature of the equilibrium which determines the arrangement of the atoms in a crystalline element is of too simple a character. In 1912 Laue showed that on passing a narrow pencil of X-rays through a crystal plate the emergent rays were capable of forming a regular, geometrical pattern of spots upon a photographic plate placed to receive the emergent beam; the pattern of spots thus produced was in agreement with the symmetry of the direction in the crystal plate in which the beam was passed. This discovery was developed and very considerably extended by Bragg, who was able to show that an X-ray

beam undergoes reflection at the surface of a crystal plate. The interpretation of the novel results indicates that the homogeneous crystal structure acts upon the X-ray beam much as a solid diffraction grating might be expected to do, and that each deflected transmitted ray is a reflection from one set of parallel planes of atoms in the crystal.

The experimental and theoretical study of the X-ray effects has been prosecuted with brilliant success by W. H. and W. L. Bragg, the result being that a method is now available which makes it possible to determine, with very great probability, the actual arrangement of the constituent atoms in crystal structure. Sufficient time has not yet elapsed for the thorough exploitation of this new and fruitful field of research, but many data are available already for comparison with the conclusions drawn from the consideration of the equilibria possible in crystal structures; it is found that the two methods do not at once lead to identical conclusions. Thus, in accordance with the first method, the structure of the diamond would be indicated as some slight modification of the cubic closest-packed assemblage of equal spheres, the modification consisting in the main of a grouping of sets of atoms which leads to the partial cubic symmetry which the diamond apparently exhibits; one particular mode of grouping which leads to the required result consists in supposing the carbon atoms formed into sets of four, tetrahedrally arranged, two oppositely orientated sets of such tetrahedral groups being distinguished. If each of these tetrahedral groups be replaced by a single point situated at the group-centre, the structure which the Bragg experiments indicate for the diamond is obtained.

The simple geometrical relationship which thus exists between the two suggested structures for diamond raises a suspicion that the particular form in which the assumption of equilibrium is stated requires qualification: that possibly the domain of the carbon atom when packed with others, as in the diamond, does not become converted into a rhombic dodecahedron, but into a polyhedron roughly tetrahedral in shape.

Leaving this particular point for the moment and turning again to Table I., it is seen that the binary compounds, like the elements, also tend to crystallise in the cubic or hexagonal systems; the axial ratios of the hexagonal binary compounds approximate very closely to the value, $a : c = 1 : 1{\cdot}6330$, calculated for the closest-packed, hexagonal assemblage of equal spheres. The values of c/a for all the known cases are: BeO $-$ 1·6365, ZnO $-$ 1·6077, ZnS $-$ 1·6350, CdS $-$ 1·6218, and AgI $-$ 1·6392.

Assemblages representing the crystal structures of the cubic and hexagonal binary compounds may be derived from the two closest-packed assemblages of similar spheres already described, by homogeneously replacing one half of the spheres by different ones of the same size. The degrees of symmetry presented by these arrangements are not so high as those of the unsubstituted assemblages; this is in accordance with the fact that the crystals themselves have not the full symmetry of the holohedral cubic or hexagonal system. Thus, on warming a hexagonal crystal of silver iodide, one end of the principal axis c becomes positively, and the other negatively, electrified. The axis c is thus a polar axis, having different properties at its two ends; this axis will be found to be polar in the model. Again, when hexagonal silver iodide is heated to 145°, it changes its crystalline form and becomes cubic; this so-called polymorphous change can be imitated in the hexagonal model by slightly shifting each pair of layers of spheres in the assemblage.

A very close agreement thus exists between the properties of the assemblages deduced and the observed properties of those binary compounds which crystallise in the cubic or hexagonal systems. The remaining 12 per cent. or so are not, in general, pseudo-cubic or pseudo-hexagonal, and it is noteworthy that they comprise those binary compounds in which the two component elements have not the same lowest valency; amongst them are the substances of the compositions, PbO, FeAs, HgO, AsS, and CuO.

On comparing the structures of the binary crystalline compounds indicated by the foregoing method of consideration with those deduced by the Braggs, discrepancies are again obvious; again, however, the former assemblage is converted into the latter by replacing groups of spheres by their group-centres. The relation thus rendered apparent is once more a suggestion that the type of equilibrium

conditions originally assumed is too simple. It will be seen, however, that the Bragg results furnish a proof of one part of the assumption made concerning equilibrium, namely, that each component atom operates separately; the discussion of the properties of crystals on the assumption that the crystal structure may be regarded as built up of similar mass-points, due to the mathematical physicists of the last century, therefore requires to be reopened. Thus, the Bragg structure of rock-salt is represented by dividing space into equal cubes by three sets of parallel planes and replacing the cube corners encountered along the directions of the cube edges by chlorine and sodium atoms alternately; each chlorine atom then has six sodium atoms as its nearest and equally distant neighbours. With which of the latter the one chlorine atom is associated to form a molecule of sodium chloride is not apparent from the nature of the crystal structure.

Time need not be now occupied with the further discussion of the crystalline structure of simple substances; until the discovery of the X-ray effects thus briefly described, no direct method of determining those structures was available, and, in view of the paucity of the experimental data, only the possibilities of arrangement could be considered in the light of the Barlow-Pope mode of treatment. It will, however, be useful to review some of the results which accrue from this latter method of regarding the problem of crystal structure in general.

Taking the general standpoint, which is also in accordance with the Bragg results, that each component atom of a crystalline structure has a separate spacial existence, and premising that the atomic domains are close-packed in the assemblage in accordance with some particular type of equilibrium law, it becomes obvious that crystalline structure presents a volume problem. The law arrived at after a careful investigation of the subject—the so-called law of valency volumes—states that in a crystalline structure, the component atoms occupy domains approximately proportional in volume to the numbers representing the fundamental valencies of the elements concerned; the student of the subject of molecular volumes will hardly accept this conclusion without convincing evidence of its correctness—it indicates, for instance, that in crystalline potassium sulphate, if the atomic volume of potassium is taken as unity, those of sulphur and oxygen each have the value two. Many different lines of crystallographic argument converge, however, to this law, and, if the latter is in the end found to be incorrect, it at least represents something fundamental which still awaits enunciation in a more generally acceptable form. A few illustrative instances may be quoted.

If valency be a volume property, the relation should be revealed in the compositions of chemical substances, especially those of composite character. The sum of the valencies in potassium sulphate, K_2SO_4, is 12, and in ammonium sulphate, $(NH_4)_2SO_4$, 24, just twice the number; the two substances are so closely related that they crystallise together to form 'solid solutions' (isomorphous mixtures). Similarly, in the alums, such as $K_2SO_4+Al_2(SO_4)_3+24H_2O$, the valencies are 12+36+96; the sum of the valencies of the water present, 96, is just twice that, 48, of those exhibited by the metallic sulphates. Similar curious numerical relationships occur in each of the well-defined series of double salts.

Again, if the valency volume law hold for two substances of different crystalline form, such as orthorhombic rubidium nitrate, $RbNO_3$, and rhombohedral sodium nitrate, $NaNO_3$, the metal, the nitrogen and the oxygen in each compound should have the respective atomic volumes, 1, 3, and 2. As the substances differ in density the absolute values of the atomic volumes of nitrogen and oxygen will differ in the two substances as examined at the same temperature; the ratios of the atomic volumes in either compound should, however, be as stated. Considering this conclusion in conjunction with the fact that these crystalline compounds represent symmetrically constructed assemblages, it would seem that the relative dimensions of the one crystal structure should be traceable in those of the other. Orthorhombic rubidium nitrate exhibits the axial ratios, $a:b:c=1{\cdot}7336:1:0{\cdot}7106$, three rectangular co-ordinates, a, b, and c, being used as the directions of reference; rhombohedral sodium nitrate exhibits $a:c=1:0{\cdot}8276$, the co-ordinates being three axes, a, making angles of 120° in one plane, and a fourth axis c, perpendicular to a. On converting the axial

system of sodium nitrate into a simple set of rectangular axes similar to those used for rubidium nitrate, the value, $a : c = 1 : 0{\cdot}8276$, becomes

$$a : b : c = 1{\cdot}7320 : 1 : 0{\cdot}7151.$$

These values approximate very closely to those obtained by direct measurement of the orthorhombic rubidium salt. It seems difficult to avoid the conclusion that the two dissimilar crystalline structures are built up by the arrangement of layers or blocks of the same relative dimensions in two different ways, the molecule of sodium nitrate, $NaNO_3$, possessing practically the same relative dimensions as that of rubidium nitrate, $RbNO_3$; this, of course, is in disaccord with the classic conception of atomic volume, but agrees entirely with the valency volume law.

Another remarkable body of evidence is found in the interpretation of many morphotropic relationships between organic and inorganic substances which have been long recognised but have hitherto eluded interpretation. The description of one or two cases will make the bearing of the law of valency volumes clear in this connection.

d-Camphoric anhydride, $C_{10}H_{14}O_3$, and *d*-camphoric acid crystallised with acetone, $C_{10}H_{16}O_4$, 1/2 $(CH_3)_2CO$, both crystallise in the orthorhombic system and exhibit the axial ratios stated in the following Table II. :—

TABLE II.

	W	$a : b : c$	$x \quad y \quad z$
$C_{10}H_{14}O_3$	60	1·0011 : 1 : 1·7270	3·2654 : 3·2618 : 5·6331
$C_{10}H_{16}O_4$, 1/2 $(CH_3)_2CO$.	74	1·2386 : 1 : 1·7172	4·0435 : 3·2646 : 5·6060

The ratio c/b is approximately the same in the two cases and general similarity exists between the two crystalline substances. It will be observed that the values of a/b are very nearly in the ratio of the sums of the valencies, W, making up the two molecular complexes, namely, $60 : 74 = 100 : 123$. This and similar cases may be more conveniently discussed with the aid of the so-called equivalence parameters; these are the edge lengths, x, y, and z, of a parallelepipedon of which the volume is W, the sum of the valencies in the molecule, and of which the linear and angular dimensions express the crystallographic axial ratios. Thus, for orthorhombic substance, $xyz = W$, and $x : y : z = a : b : c$; the equivalence parameters of the two substances under discussion are given in the table, and it will be seen that whilst y and z are almost identical for the two, the z values differ considerably. This correspondence indicates clearly that in passing from camphoric anhydride to the acetone compound of the acid the mass added to the molecular complex, $H_2O + 1/2\ (CH_3)_2CO$, occupies a volume proportional to the number of valency units which it contributes to the structure.

A very remarkable relation has been long recognised between the crystalline forms of the three minerals chondrodite, $Mg_3(SiO_4)_2$, $2Mg(F,OH)$, humite, $Mg_5(SiO_4)_3$, $2Mg(F,OH)$, and clinohumite, $Mg_7(SiO_4)_4$, $2Mg(F,OH)$; the crystalline forms are referable to three rectangular directions, a, b, and c, and the ratio $a : b$ is practically the same for all three minerals. The relationship is at once elucidated by the law of valency volumes in a simple manner. In the molecules of the three substances the sums of the valencies of the constituent atoms are respectively 34, 48, and 62; it follows from the law that these numbers are proportional to the relative volumes of the several molecules. The ratios, $a : b : c$, being known, the dimensions can be calculated of solid rectangular blocks having these volumes and having edge lengths proportional to the axial ratios, $a : b : c$. The equivalence parameters, x, y, and z, thus calculated are given in Table III.; the first observation of importance to be made is that the equivalence parameters, x and y, remain practically constant throughout the series of three minerals.

It will be seen that chondrodite and humite, and humite and clinohumite, differ in molecular composition by the quantity, $Mg_2(SiO_4)$; they form a series in which the increment of composition is $Mg_2(SiO_4)$. Subtracting this increment from the composition of chondrodite, the residue, $Mg_2(SiO_4)$, $2Mg(F,OH)$,

is left. This is the composition of the mineral prolectite, and the increment, $Mg_2(SiO_4)$, is the composition of the mineral forsterite.

If the law of valency volumes be correct the equivalence parameters of forsterite should be the x and y of the first three minerals, and a value z which is the difference between the z values of chondrodite and humite, or of humite and clinohumite; further, prolectite should have x and y values identical with those of the other four minerals and a z value which is the difference of the z values of chondrodite and forsterite. It is thus possible to calculate the equivalence parameters of forsterite and prolectite without using data determined on these two minerals, and to compare the values so obtained with those calculated from the observed axial ratios of forsterite and prolectite. All the values referred to are given in Table III., and it will be obvious that the agreement between the calculated and the observed equivalence parameters is very close; as this agreement could not occur without the operation of the law of valency volumes, which was deduced from entirely different data, strong confirmation of the accuracy of the law is provided.

TABLE III.

Minerals	W	Axial Ratios	Equivalent Parameters			z/W
		a : b : c	x	y	z	
Chondrodite . .	34	1·08630 : 1 : 3·14472	2·3367	2·1510	6·7644	0·19895
Humite . . .	48	1·08021 : 1 : 4·40334	2·3343	2·1610	9·5155	0·19824
Clinohumite . .	62	1·08028 : 1 : 5·65883	2·3384	2·1646	12·2491	0·19756
Prolectite : observed	20	1·0803 : 1 : 1·8862	2·3130	2·1414	4·0385	0·19977
Prolectite : calculated	20	1·0818 : 1 : 1·8618	2·3365	2·1589	4·0211	0·19968
Forsterite : observed	14	0·9296 : 1 : 1·1714	2·3426	2·1778	2·7442	0·19601
Forsterite : calculated	14	0·9240 : 1 : 1·1741	2·3365	2·1589	2·7433	0·19585

The several illustrations of the operation of the law of valency volumes have been quoted in detail for the purpose of showing how difficult it is to avoid the conclusion that this deduction represents some physical reality. It may be traced in connection with quantitative data of other kinds; during the last few years it has been very successfully applied by Le Bas to the interpretation of the molecular volumes of liquid substances.

From what has been already said it will be seen that the great problem as to the relation between crystal structure and chemical constitution, of which the solution seems imminent, is a stereochemical one; assemblages must be built up in accordance with the principle of homogeneity and in some form of close-packing, in which each component atom of a chemical molecule is represented as the sole occupant of some specific solid area. The properties of these assemblages must also be in agreement with the crystallographic measurements and the X-ray photographs yielded by the substances represented.

A brief indication may be given of what has been already effected in this connection. The normal paraffin hydrocarbons of the general composition C_nH_{2n+2} consist of a chain of the composition $(CH_2)_n$, to each end of which one hydrogen atom is attached; in accordance with the principles already indicated, a close-packed assemblage of the empirical composition CH_2 can be constructed from carbon and hydrogen spheres of the respective volumes 4 and 1, of such a nature that it can be divided by planes into blocks, each made up of strings of the composition $(CH_2)_n$, or $.CH_2.CH_2 \ldots . CH_2 . CH_2$. At each plane of cleavage of the assemblage hydrogen spheres can be inserted in appropriate numbers so that close-packing is restored when the cleavage faces are brought together again; the assemblage will then have the composition $H . (CH_2)_n . H$, and may be geometrically partitioned into units each representing one molecular complex of a normal paraffin. It is noteworthy that these units exhibit the configurations indicated by the van 't Hoff-Le Bel conception for the normal paraffins. Other assemblages can be constructed which represent in a similar manner the secondary and tertiary paraffins, and all these assemblages are of one particular geometrical type, that which corresponds to the chemical behaviour characteristic of the paraffins. In these assemblages

replacements may be effected so as to introduce new geometrical features of arrangement corresponding to the presence in the molecule of an ethylenic or an acetylenic bond, and thus other classes of hydrocarbons can be represented in accordance with the conception of close-packing; the process can be extended to the polymethylene and aromatic hydrocarbons and to their substitution derivatives, and throughout a close correspondence is observed between the numbers of isomerides possible, with their constitutions and configurations, and the experimental facts.

Many considerations indicate the fruitfulness of the mode of regarding organic substances just briefly sketched; one may be more particularly specified. An assemblage representative of benzene has been suggested which accords with the crystalline form and chemical properties of the hydrocarbon, and can be geometrically partitioned into units, each representing a single molecule. The equivalence parameters of the substance are

$$x : y : z = 3{\cdot}101 : 3{\cdot}480 : 2{\cdot}780.$$

The dimension y is twice the diameter of a carbon sphere, and that of z slightly less than the sum of the diameters of a carbon and a hydrogen sphere. Now a dimension approximating closely to the z value for benzene can be found amongst the equivalence parameters of large numbers of aromatic compounds, indicating that in these crystalline substances the benzene complexes are stacked one upon the other so as to preserve the z dimension, but that the columns so formed are pushed apart in the derivatives to an extent sufficient to admit of the entrance, in close-packing, of the substituting radicles. A few cases of this kind were quoted by Barlow and myself, and many others were discovered by Jerusalem;[6] quite recently the subject has been subjected to a very thorough quantitative examination by Armstrong, Colgate, and Rodd.[7] The exhaustive nature of the experimental work of these latter authors and the care with which their conclusions are drawn leave little room for doubt as to the accuracy of their main contention, namely, that the crystallographic method affords material from which the stereochemical configurations of aromatic substances can be deduced.

If crystallography is to be used as a tool in the service of stereochemistry in anything like the way which has been briefly sketched in this address, a number of important results should accrue. We have seen that in the structure assigned to rock-salt, each sodium atom is identically related to six chlorine atoms; only when the crystal is disintegrated by solution in water does the necessity arise for a choice to be made, the sodium atom then selecting one particular chlorine atom as a mate. Even then the sodium chloride molecule present in solution appears to spend the greater part of its time in dissociation, namely, in the act of changing its partner. There is thus in the theory of crystal structure something which bears a superficial relationship to electrolytic dissociation, and the further study of this aspect of the subject may be fruitful.

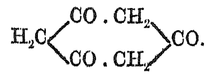
Again, the solid crystalline structures which we have attempted to build up present, as one essential feature, the property that they can be partitioned geometrically into unit cells, each composed of one molecule of the substance; thus, the rock-salt structure can be partitioned into cells each representing the molecule NaCl. In this instance, the partitioning can be performed in a variety of ways corresponding to the allocation of one particular sodium atom to either of six chlorine atoms; the alternative modes of partitioning lead to the production of molecular units of identical configuration. In many cases, however, alternative methods of geometrically partitioning the assemblage representing the crystalline structure do not yield units of the same configuration; thus, the assemblage representing phloroglucinol can be geometrically partitioned in two distinct ways. Each of these gives a unit of the composition $C_6H_6O_3$, but the configuration of the unit of the one partitioning corresponds to the chemical structure of the 1 : 3 : 5–trihydroxybenzene,

$$\mathrm{HC}\begin{array}{l}\diagup\mathrm{C(OH)\,.\,CH}\diagdown\\ \diagdown\mathrm{C(OH)\,:\,CH}\diagup\end{array}\mathrm{C(OH)}$$

[6] *Trans. Chem. Soc.*, 1909, **95**, 1275.

[7] *Trans. Chem. Soc.*, 1910, **97**, 1578; *Proc. Roy. Soc.*, A, 1912, **87**, 204; 1913, **89**, 292; 1914, **90**, 111.

whilst the other exhibits the structure of the symmetrical triketohexamethylene,



A new suggestion is thus made to the effect that tautomerism consists in the possibility of geometrically partitioning the close-packed assemblage in two or more alternative ways, each giving molecular units of the same composition but of different constitutions. The idea that in the occurrence of tautomerism some component atom wanders from one position to another in the molecule is thus rejected; the change in constitution arises from the transference of atoms as between two or more molecules. As the older conceptions of the mechanism of tautomerism do not provide a satisfactory explanation of the experimental facts, the suggestion now made is perhaps worthy of consideration.

The new line of work has many bearings upon the subject of chemical change; thus, the assemblage which is assigned to acetylene (or methylacetylene) is convertible, by symmetrical distortion, into that representing benzene (or the 1 : 3 : 5-trimethylbenzene, mesitylene). Further, the great change in chemical behaviour which accompanies many types of chemical substitution is possibly connected with the manner in which the actual atomic volumes are affected by the replacement; on converting benzene, in which the atomic volumes of carbon and hydrogen are as 4 : 1, into bromobenzene, a considerable increase in molecular volume occurs. The atomic volumes of carbon and hydrogen still, presumably, preserve the 4 : 1 ratio, and the volume appropriated by the entering bromine atom is approximately the same as that occupied by each hydrogen atom already present; the actual atomic volumes of carbon and hydrogen must thus be supposed to have increased during the production of bromobenzene. It can hardly be supposed that this fundamental volume change, even apart from a distortion of the aromatic ring arising from slight inequality of hydrogen and bromine atomic domains in the molecule, could occur without the exhibition of considerable differences in chemical properties as between benzene and bromobenzene.

Whatever view may be taken as to the accuracy of the conclusions concerning the relation between crystal structure and chemical constitution which are briefly discussed in the present Address, no critic will be disposed to doubt that wide developments in chemical science will result from the cultivation of crystal study; it seems clear that any satisfactory theory of the solid state must be largely crystallographic in character. The chief hindrance to progress at present consists in the lack of chemists trained in modern crystallographic methods; in my own country the only school in which chemical students were trained in Crystallography, dissociated from Mineralogy, was founded by Dr. Henry E. Armstrong and Sir Henry A. Miers in 1886. After doing a vast amount of valuable educational work this school has recently been allowed to become extinct.

In a Presidential Address to the Mineralogical Society in 1888, Mr. Lazarus Fletcher remarked that 'a knowledge of the elements of Crystallography, including the mechanics of crystal measurements, ought to be made a *sine qua non* for a degree in Chemistry at every University.' Twenty-five years later we find that no European University has applied this principle, and in consequence the chemical crystallographer has the greatest difficulty in making himself intelligible to his purely chemical colleagues. May I, in concluding, express the hope that the Colonial Universities, less fettered by tradition than their older sisters, may lead in the work of placing the subject of crystal structure in its legitimate position as one of the most important branches of modern Physical Chemistry?

The following Papers were then read :—

1. *Residual Affinity and Co-ordination. By* Professor GILBERT T. MORGAN *and* HENRY WEBSTER MOSS.

The molecular structures now known as co-ordination compounds owe their stability not merely to the forces (principal valency and residual affinity)

emanating from the central atom, but also to the mutual attractions exerted on one another by the co-ordinating or associating radicals or groups. It is precisely those radicals or groups possessing considerable residual affinity which function most frequently in the formation of co-ordinated complexes. The general tendency to form hydrated and ammoniated metallic salts is to be attributed in the main to the capacity for association exhibited by water and ammonia molecules respectively.

The phenomenon of co-ordination may be compared with the formation of fog in moist air containing minute dust-particles, and it is even more closely akin to the formation of the large ions of the atmosphere by the association of small ions with uncharged invisible water-drops.

The size of the atomic volume of the central element has a threefold influence on the stability of co-ordination compounds. First, if the atomic volume is small, the residual affinity of the atom is exerted in a more concentrated form. Secondly, the co-ordinating molecules or radicals can approach nearer to the centre of the central atom when its volume is small and therefore nearer to one another so that their mutual attractions become more effective. Thirdly, as the dimensions of the co-ordinating molecules or radicals are of molecular or atomic magnitude, these segregating units will fill more completely the available space round an atom of small volume than that round an atom occupying a larger sphere. This filling up of the available space also conduces to stability, as is manifested by many stereoisomeric compounds.

The number and arrangement of the associating units have also an important bearing on the stability of the co-ordination complex. It is obvious that the most stable system will be that in which there is a symmetrical distribution of the forces interacting between the associating units, a condition which is attained by taking such a number of units that they can be arranged symmetrically over the surface of a sphere. This problem has but few solutions, inasmuch as there are only five regular solids, the tetrahedron, octahedron, cube, icosahedron, and dodecahedron, with four, six, eight, twelve, and twenty vertices respectively. These integers will be the co-ordination numbers corresponding with the theoretically possible most stable systems. Molecular aggregations exist corresponding with four of these arrangements—that is, with all possible cases except that of the dodecahedron. There are also examples of less symmetric arrangements which become stable in certain circumstances.

In addition to the centric co-ordination complexes with associating units arranged round a central atom, it is highly probable that co-ordination sometimes leads to cyclic arrangements, as, for example, in the following instances:— The basic glucinum acetate, butyrate, &c., the dichloride and dibromide of molybdenum, and the reduction products of the pentahalides of columbium and tantalum.

As an example of the application of the co-ordination theory to compounds of technical importance may be cited the case of the lakes of acidic colouring-matters developed in mordant dyeing. The simplest of these are the iron, chromium, and cobalt lakes of the *ortho*-quinoneoxime dyes, which are undoubtedly internally co-ordinated compounds.

2. *A Device for the Representation of the Natural Classification of the Elements. By* Professor ORME MASSON, *F.R.S.*

TUESDAY, AUGUST 18.

Joint Discussion with Section A on the Structure of Atoms and Molecules.—See p. 293.

WEDNESDAY, AUGUST 19.

The following Papers were read :—

1. *A New Method for the Determination of Vapour Pressures and an Examination of a Source of Error in certain Dynamical Methods. By* F. H. CAMPBELL, *M.Sc.*

Since none of the accepted methods is suitable for the determination of the vapour pressure of a binary mixture of a volatile with a non-volatile liquid a new method has been devised for the purpose.

The principle used is that of allowing a liquid saturated with a suitable gas, usually hydrogen, to evaporate into an enclosed space filled with the same gas at the same temperature and pressure, the latter being approximately atmospheric. The extra pressure exerted by the vapour is measured by means of an open mercury manometer after the volume has been restored to its original value by means of a levelling vessel. The method can be applied to volatile organic liquids of many kinds, since they come into contact with glass and mercury only. The liquid is enclosed in a glass tube projecting through a rubber stopper, which closes an opening at the bottom of the vessel, the stopper being protected from the action of the liquid by a layer of mercury. When the apparatus has reached the temperature of the constant temperature bath in which it is immersed, the tube, previously deeply scratched, is broken by gentle sideways pressure on the projecting end. Saturation of the gas by the vapour is hastened by gently shaking the apparatus.

Experiments have been made with the following liquids and gases: Methyl alcohol, ethyl alcohol, diethyl ether, carbon disulphide, chloroform and water, evaporating into carbon dioxide, air, hydrogen, and, in the case of chloroform, nitrogen in addition. In every case the values obtained, though very concordant, are lower than the most reliable results obtained by the ordinary static method. The magnitude of the error evidently depends on the solubility of the particular gas in the particular liquid as it diminishes in each case, except that of water, in the order carbon dioxide, air, hydrogen. With water at 60° C. the results obtained with air and hydrogen are practically identical. The error when hydrogen is used is generally less than 1 per cent., and it is considered that the agreement is sufficient, as with mixtures the ratio between the observed pressure of the solution and that of the pure volatile solvent is to be considered. With air the errors are from 2 to 6 per cent., and it is concluded that methods depending on the saturation of a current of a gas passing through or over solution and pure solvent must therefore involve more or less error from this cause, a fact which does not seem to have been appreciated in the past. Perman ('Proc. Roy. Soc.' 1903, **72**, 72) and Krauskopf ('J. Phys. Chem.' 1910, **14**, 489) obtained satisfactory results with water, although those of Regnault ('Ann. Chim. Phys.' 1845 (3), **15**, 129) and Tammann ('Wied. Ann.' 1888, **23**, 322), which are lower than those obtained by the static method, are brought into satisfactory agreement with these upon the author's assumption, which indicates that the errors introduced by the presence of a dissolved gas are negligible under certain conditions.

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2. *A New Method for determining the Specific Heats of Liquids. By* ERNST JOHANNES HARTUNG, *B.Sc.*

The method described, which was suggested by Professor Orme Masson, is a modification of the mixture method for determining specific heats. The principle consists in measuring the lowering in temperature of a known amount of the particular liquid on the introduction of a definite weight of dry ice contained in a thin glass bulb. The calorimeter is a thin glass vessel of about one hundred cubic centimètres capacity, and is supported inside a silvered Dewar tube. A well-fitting rubber stopper closes the mouth of this tube, making the apparatus airtight. Through the stopper is fitted a Beckmann thermometer and also a thin glass stirring rod, the lower end of which is suitably shaped to receive the small ice-bulb. A third hole, lined with glass and closed with a

well-fitting glass stopper, passes through the rubber stopper and serves for the introduction of the ice-bulb. This last consists of a small sealed thin glass cylindrical bulb, containing a definite weight of distilled water and also as much silver gauze as possible. The last ensures rapid heat conduction, and makes the bulb heavy enough to sink in dense liquids. The bulb is suspended by a fine platinum wire.

The liquid to be experimented with is introduced into the calorimeter by means of a standardisation pipette, and the apparatus is closed until constant temperature is attained. The ice-bulb has meanwhile been frozen in a mercury bath supported in an ordinary freezing-point apparatus. When the temperature of the mercury is constant at from $-3°$ to $-4°$, the bulb is removed by its suspension and rapidly introduced into the lower part of the stirring rod in the calorimeter. The liquid is then stirred by hand until constant temperature is again attained, which usually requires about three minutes. Radiation corrections are then applied and the specific heat of the liquid calculated, the heat capacity of the ice-bulb being accurately known. The experiments should be performed in a room regulated to constant temperature.

The advantages claimed for the method are its simplicity, its rapidity, and its accuracy. Experiments with water at 25° C. gave consistent results agreeing to within 0·4 per cent. When ether was used, it was found necessary to coat the rubber stopper with tinfoil in order to protect it. The results with ether at 25° C. agreed to within 1·4 per cent. (the vapour pressure of ether at this temperature is 545 mm.). The specific heats of several sulphuric-acid-water mixtures were also measured and compared with the classical results of J. Thomsen. The average divergence was less than one per cent. Further measurements with different liquids are now in progress.

The apparatus described is not suitable for a viscous liquid (such as glycerine) owing to inefficient stirring. By having another liquid than water in the carrier-bulb, the scope of the method can probably be extended.

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3. *The Influence of Weather Conditions upon the Amounts of Nitric Acid and of Nitrous Acid in the Rainfall near Melbourne, Australia. By* V. G. Anderson.

Daily determinations of the amounts of nitric acid and of nitrous acid in the rainfall at Canterbury, near Melbourne, have been made since November 1, 1912. The results to February 28, 1914, when correlated with meteorological data for Melbourne and daily isobaric charts of Australia, reveal the existence of a relation between weather conditions and the amounts of nitrogen acids in rain-water.

The concentration of nitric acid reached a maximum in summer, a minimum in winter, and an intermediate position during autumn and spring. The concentration of nitrous acid reached a maximum in winter, and a minimum in summer. The ratio of nitric nitrogen to nitrous nitrogen was highest in summer and lowest in winter. On many occasions during winter the ratio was approximately as 1 : 1. A relation between atmospheric temperature and this ratio was noted. Its nature was shown by plotting the mean minimum temperature of each month with the mean monthly ratios, the curve being of the same type as those which express changes of chemical velocity with temperature. The ratio is doubled for equal increments of temperature. From the results it would appear that in rain-water nitric and nitrous acids are formed in equal molecular proportions, and that, if the ratio could be determined instantly, or before any change could ensue, it would invariably be as 1 : 1. In cold weather the velocity is retarded to such an extent that little change occurs even after comparatively long periods; hence the increased amounts of nitrous acid found in winter. In hot weather, the velocity being greatly increased, the residual amounts of nitrous acid are very small, nearly all having been converted into nitric acid. The facts point to atmospheric nitrogen peroxide as the source of nitric and nitrous acids in rain-water, as this gas reacts with water, forming these acids in equal molecular proportions.

In a graph plotted with daily concentrations of total (nitric plus nitrous) nitrogen as abscissæ, and with rainfall as ordinates, the points are found to arrange themselves into a series of rectangular hyperbolæ. Further, each group of points lying along a particular curve is found to correspond with falls of rain occurring during one particular type of weather. From this it follows that for a particular type of weather (1) the concentration of oxidised nitrogen varies inversely as the rainfall; (2) the product of the concentration and the rainfall is constant; (3) the total weight per unit area of oxidised nitrogen precipitated with rain falling during twenty-four hours is constant. In brief, the amount of oxidised nitrogen per acre carried down by rain falling on any day is a function of the type of weather, and, within certain limits, is independent of the amount of rainfall. These facts may be explained by assuming that for each type of weather there exists in the air a definite concentration of nitrogen peroxide, and that this soluble gas is completely washed out of the air by the first portions of a shower: any further rain falling through the now purified air not increasing the amount of oxidised nitrogen in the rain-water, but, by dilution, decreasing the concentration.

Nine well-defined recurring types of weather have been investigated. These may be classified into three groups, as follows: (1) Antarctic types; (2) Tropical types; (3) Divided control (Antarctic and Tropical) types. The accompanying table shows the number of examples of each type investigated, together with the oxidised nitrogen constant in pounds per thousand acres, for each type.

	Number Examined	Oxidised Nitrogen Constant. Pounds per 1,000 acres
Antarctic Types—		
ʌ-shaped Antarctic depressions (*a*) rear	35	1·5
ʌ-shaped Antarctic depressions (*b*) crest	28	2·5
ʌ-shaped Antarctic depressions (*c*) front	10	4·1
Tropical Types—		
Tropical (or monsoonal) depressions (*g*) spring and autumn type	6	16·0
Tropical (or monsoonal) depressions (*h*) summer type	3	24·0
Tropical (or monsoonal) depressions (*i*) 'heat-wave' type	2	35·0
Divided Control Types—		
(*d*) Antarctic depressions with *slight* Tropical influence	6	6·1
(*e*) Antarctic depressions with *strong* Tropical influence	4	8·5
(*f*) Tropical depressions with *slight* Antarctic influence	5	12·0

4. *A Comparison of the Phenomena of the Occlusion of Hydrogen by Palladium and by Charcoal. By* Dr. A. Holt.

When all the known facts concerning the occlusion of hydrogen by palladium and by charcoal are examined and compared, it appears that, in the case of charcoal, absorption and surface condensation, without chemical action, occurs, but with palladium the evidence is in favour of the formation of a compound in addition to surface condensation. In both cases there is evidence that allotropes of the occluding solids exist, one allotrope occluding gas with far greater avidity than the other.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *Non-Aromatic Diazonium Salts.* *By* Professor GILBERT T. MORGAN *and* JOSEPH REILLY.

The diazotisability of an organic primary amine is in all probability connected with the presence in the basic molecule of an unsaturated group, for it has not yet been found possible to diazotise the salt of any primary base having its amino-group attached directly either to a fully saturated radical or to a completely hydrogenised ring.

It is, however, not essential that the unsaturated radical should be aromatic or homocyclic in character, and certain non-aromatic amines are known to possess in varying degrees the property of diazotisability. This property has been demonstrated in the case of the following heterocyclic bases not merely by detecting the presence of diazo-compounds in solution, but also by the isolation of the diazonium salts.

4-Amino-1-phenyl-2 : 3-dimethylpyrazolone (4-amino-antipyrine) when diazotised with ethyl nitrite in hydrochloric acid furnishes a well-defined crystallisable diazonium hydrochloride ($C_{11}H_{11}ON_4Cl)_2HCl$ from which the crystalline dichromate $(C_{11}H_{11}ON_4)_2Cr_2O_7$; aurichloride $(C_{11}H_{11}ON_4)AuCl_4$ and platinichloride $(C_{11}H_{11}ON_4)_2PtCl_6$ of normal composition have been prepared.

4-Amino-3 : 5-dimethylpyrazole, a base containing no aromatic substituent whatever, gave rise to a remarkably stable colourless diazonium chloride, crystallising with great facility, and permanent under ordinary atmospheric conditions. Although the parent base forms a dihydrochloride, $C_5H_9N_3$, 2HCl, one of the salt-forming centres disappears in diazotisation, the diazonium chloride $C_5H_7N_4Cl$ corresponding in composition with the salt of a monacidic base.

The replacement of the diazonium group by a triazo-radical restores this suppressed salt-forming centre, the product, 4-triazo-3 : 5-dimethyl-pyrazole being a basic compound which has the remarkable property of developing characteristic colorations with phenols in alkaline solutions.

Aminomethyltriazole can be diazotised in nitric-acid solution without loss of diazo-nitrogen, although in hydrochloric acid effervescence is copious even at 0° C.

The diazotisability of wool is usually attributed to the presence in this material of aromatic amino- groups; but in view of the foregoing results it appears possible that the interaction of wool and nitrous acid may be due in part to the presence of heterocyclic rings comparable with those of the pyrazole, triazole, or thiazole series.

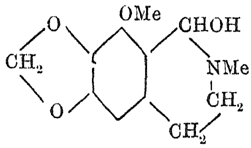
2. *The Synthesis of Isoquinoline Alkaloids.* *By* Professor R. ROBINSON.

Many pseudo- bases of isoquinoline type—for example, cotarnine, hydrastinine, berberine, isoquinoline methyl hydroxide—readily undergo condensations with the most varied classes of organic substances, and the greater number of these reactions can be generalised in the scheme :—

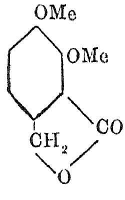
$$\diagup\!\mathrm{CHOH{-}NMe{-}} + \mathrm{HR} \rightarrow \mathrm{{-}\overset{\displaystyle R}{\overset{|}{C}}H{-}NMe{-}} + \mathrm{H_2O}$$

The interest of these condensations is very much enhanced by the fact that they yield substances closely allied in constitution to the naturally occurring isoquinoline alkaloids, and for instance cotarnine (I) with meconine (II) gave a small yield of α-gnoscopine (III) resolvable by means of *d*-bromocamphorsulphonic acid into *d*-narcotine and *l*-narcotine, the latter proving identical with the natural base occurring in opium. Cotarnine and nitromeconine react with great facility and give rise to a nitro- base from which by elimination of the

nitro- group a stereoisomeric β-gnoscopine is obtained, and this is convertible to α-gnoscopine by prolonged heating with aqueous alcohol. By similar methods a stereoisomeride of hydrastine has been synthesised. These condensations also open up a method of synthesis of phenanthrene alkaloids (morphine group), and



(I)



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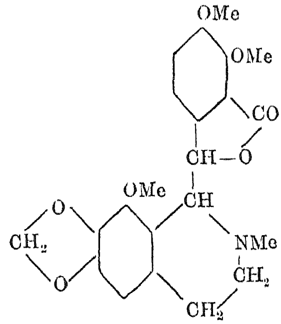

(III)

it is along these lines that further work is being prosecuted. Up to the present an isomeride of apomorphine dimethyl ether is the only example of the application of the process. It is probable that the mechanism of the pseudo- base condensation involves the stages

$$\diagup CHOH-\underset{Me}{N}- \rightarrow -CH=\overset{OH}{\underset{Me}{N}}- + HR \rightarrow -CH=\overset{R}{\underset{Me}{N}}- \rightarrow -\overset{R}{C}H-NMe-$$

a view which receives support from the remarkable rapidity of the reactions and from the observation that they occur with greatest readiness in ionising solvents. It is also considered extremely probable that such condensations have an important *rôle* in the synthesis of alkaloids in plants.

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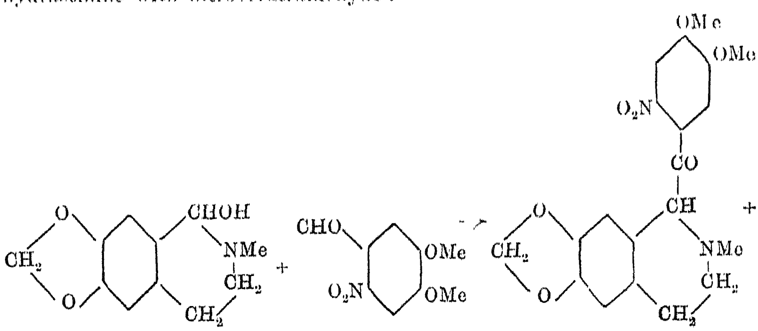
3. *The Condensation of Cotarnine and Hydrastinine with Aromatic Aldehydes.* *By* Mrs. G. M. Robinson, *M.Sc.*

The condensation of hydrastinine with *o*-nitrobenzaldehydes takes place in accordance with the following scheme, which represents the condensation of hydrastinine with *nitroveratraldehyde*:—



It is hoped that this substance will form a suitable starting-point for a synthesis of dicentrine. On reduction by stannous chloride these bases yield amino ketones, which can then be further reduced to fully saturated bases by means of amalgamated zinc and hydrochloric acid. Several bases similar to the above have been prepared.

4. *The Influence of Substituents on the Velocity of Saponification of Phenyl Benzoate.* *By* Dr. H. McCombie.

5. *The Colouring Matters of certain Marine Organisms.* *By* Dr. A. Holt.

The colouring matters of *Diazona viridis* and *Syntethys Hebridicus* have been shown to be due to a green body very similar to chlorophyl, and a purple substance which appears to be a dibromindigo. This purple compound is only found on the surface of the Ascidian Colony, and it is concluded that it acts as an oxygen carrier, since when the organism is alive and healthy it is not produced. Under these conditions it would be maintained as the colourless leuco body, but with the death of the colony changes in metabolism take place and oxidation produces the colour. The green pigment is very possibly due to a symbiotic alga. These pigments have been compared with those obtained from different species of *Murex* and from *Bonellia.*

6. *The Corrosion of Iron and Steel by Artesian Waters in New South Wales.* *By* Professor Fawsitt.

7. *The Use of Waste Gases of Combustion for Fire Extinctive and Fumigating Purposes.* *By* Dr. G. Harker.

The experiments of Clowes and Feilman on the extinctive properties of flames have shown that the flames of ordinary substances are extinguished when the oxygen in the atmosphere is reduced to about 15 per cent. The extinction of solid material, as for example ignited coal, requires a lower percentage of oxygen, and takes time owing to the need for a cooling effect. Flue gas from ordinary boilers burning coal or coke does not generally contain more than 9 or 10 per cent. of oxygen, and if pumped into a space so as to displace the air will render the atmosphere fire-extinctive and will also be destructive to rats and other vermin. For practical purposes the flue gas must be cleaned and cooled before use, and formaldehyde vapours are sometimes added to it. Several installations making use of this process are now in operation.

8. *The Extraction of Radium from Australian Ores.* *By* S. Radcliff.

(1) A short account was given of all known occurrences of radioactive minerals in Australia.

(2) The methods now in use at the Sydney works of the Radium Hill Co. for the extraction of radium from the complex ore found at Olary, near Broken Hill, were described.

(3) The results of an examination of the various radioactive precipitates separated in the course of the works operations were given, together with the methods employed in working up preparations of ionium and actinium.

9. *The Inversion of Cane-sugar by Acids in Water-alcohol Solutions.* *By* George J. Burrows, *B.Sc.*

The rates of inversion of cane-sugar by hydrochloric acid and sulphuric acid have been determined in water-alcohol solutions up to 75 per cent. alcohol. In both cases a minimum velocity has been found for a solution containing about 50 per cent. alcohol by volume. From the results obtained it is evident that the velocity of inversion is not proportional to the concentration of hydrogen ions in such a series of solvents. The similarity between the curve representing the variation of the inversion velocity with the composition of the solvent and the viscosity curve for these mixtures led the author to conclude that the rate of catalysis by acids is a function of the fluidity of the medium.

The results for the inversion velocity show that the latter is not directly

proportional to the fluidity of the solvent. It was assumed that the effect of fluidity on catalysis is similar to its effect on ionic mobility as determined by electrical conductivity. Hence by dividing the inversion velocity by the conductivity of the acid in the particular solvent the result obtained expresses the activity of the catalytic ion in this medium. In this way it was found that the activity was far greater in 70 per cent. alcohol than in water.

It was therefore concluded that catalytic hydrolysis is retarded by the addition of water in the same way as esterification and other similar catalytic reactions.

MONDAY, AUGUST 24.

The following Papers were read:—

1. *On Explosions in Gases (with Demonstration).*
By Professor H. B. Dixon, *F.R.S.*

2. *Chemical Crystallography (with Demonstration).*
By Professor W. J. Pope, *F.R.S.*

TUESDAY, AUGUST 25.

Joint Discussion with Section M (Agriculture) on Metabolism.—
See p. 663.

The following Paper, opening a Discussion on Cyanogenesis in Plants, was then read:—

The Cyanogenetic Plants of New South Wales.
By James M. Petrie, *D.Sc.*

Of the plants growing in New South Wales, over a thousand species have been examined for hydrocyanic acid and cyanogenetic glucosides. Sixty of these gave positive results with sodium picrate paper. These include forty-four species native to New South Wales in seventeen Natural Orders.

Some plants, well known to be cyanophoric in Europe, when grown in this State have never given any reaction, although tested in all seasons.

Only a few were found to evolve free hydrocyanic acid, naturally, but all showed the presence of a glucoside and enzyme.

When the natural enzymes in these plants were killed by boiling water, the reaction to sodium picrate paper ceased; if then a few drops of emulsin, prepared from sweet almonds, were added, positive reactions were again obtained, showing that in all cases the glucosides present in the plants were capable of being hydrolysed by emulsin.

Of the sixty species stated, twenty are grasses, and these include eleven species indigenous to this State. The *Sorghum vulgare* examined by Dunstan and Henry was found to lose its glucoside when fourteen inches high, while the Australian-grown plant retains it when four feet high, and mature. Both glucoside and enzyme slowly disappear with air-drying.

One hundred and fifty species of grasses were tested systematically for seasonal variations, and some were found to give negative results at particular seasons. Two species of grasses alone evolved free hydrocyanic acid, and only one of these is available for grazing. This is the only one, except the sorghums, which has been associated with fatalities among stock.

Among the non-cyanogenetic grasses, thirty-three species contained emulsin-like enzymes.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION: PROFESSOR SIR T. H. HOLLAND, K.C.I.E., F.R.S.

The President delivered the following Address at Sydney, on Friday, August 21:—

EXACTLY eighty-three years from the day of our arrival at Sydney, Edward Suess was born in London. Thus the day, as much as the circumstances of our meeting so far from home, serves to remind us of one who was great enough to recognise the fact that geological evidence from any part of the world has the same value as that obtained in the little continent which has been the most prolific in the products of nomenclature and the most productive in text-books.

Since the days of Charles Lyell no geologist has been so conspicuously successful in analysing the accumulated mass of evidence, in bringing together the essential facts from all lands, and in compensating for the local excesses of literature. Only those of us who, by long absence from Europe, have felt the full disadvantages of having to express our thoughts in alien terminology can appreciate the real value of Suess's great work. His death since our last meeting makes a conspicuous mark in the history of geological science.

A meeting of the British Association in Australia brings home forcibly to the members of Section C the fact that British Imperial geology is really 'the science of the Earth'; partly for this reason one feels inclined to get outside the science and take a survey of some of its suburbs. Not many of them have been left untraversed by my distinguished predecessors in this chair; but there has been of recent years a tendency to avoid the inner Earth, which has rightly been described as 'the inalienable playground of the imagination,' and consequently, therefore, common land to the geologist as well as the geodesist, physicist, and mathematician.

The geologist who looks below the purely superficial phenomena of the crust is generally regarded as straying beyond his province; but the desire to see the birth-certificate of some of the strange and often unacceptable 'causes' which the mathematical physicist offers us is a pardonable form of curiosity. Our ideas regarding intra-telluric conditions are even proving to be of economic value, one of the most recent and unexpected results of the kind being that just established by Baron von Eötvös in Hungary,[1] whose predictions now bid fair to outstrip those of the 'diviner'! Having noticed the low gravity values over the great cores of rock-salt in the Transylvanian 'Schlier,' he finds similar defects of gravity in the same region over certain of the Sarmatian and Pontian domes, which probably owe their shape to subterranean salt-plugs and are now found to be great storehouses of natural gas, which, with or without liquid petroleum, is commonly found with the saline 'Mediterranean' facies of the Upper Tertiary in Eastern Europe. Baron von Eötvös also finds that on the eastern margin of the Great Hungarian Plain, where the younger Tertiary beds are completely concealed by a mantle of alluvium, mud-volcanoes and gas-springs are sometimes found in areas of marked gravity defect, and some of these are now also being drilled for natural gas.

[1] *Comptes Rendus, XVIIème Conf. de l'Assoc. Géodés. Internat.*, Hamburg, 1912, pp. 427, 437.

When our ideas of the state of affairs below the surface thus begin to yield economic results, there is hope that they are at last steadying down, becoming more settled, and indeed more 'scientific.' It may not be unprofitable, therefore, to review some of the advances recently made in developing theoretical conceptions regarding the interior of the Earth that are of direct importance to geologists. In undertaking this review I am conscious of the fact that I shall be traversing ground that is generally familiar to all, and much of it the special property of specialists whose views I hesitate to summarise and should not dare to criticise. As the author of the 'Ingoldsby Legends' said of the only story that Mrs. Peters would allow her husband to finish, 'The subject, I fear me, is not over new, but will remind my friends—

"Of something better they have seen before."'

The intensity and quantity of polemical literature on scientific problems frequently varies inversely as the number of direct observations on which the discussions are based: the number and variety of theories concerning a subject thus often form a coefficient of our ignorance. Beyond the superficial observations, direct and indirect, made by geologists, not extending below about one two-hundredth of the Earth's radius, we have to trust to the deductions of mathematicians for our ideas regarding the interior of the Earth; and they have provided us successively with every permutation and combination possible of the three physical states of matter—solid, liquid, and gaseous.

Starting, say, two centuries back with the astronomer Halley, geologists were presented with a globe whose shell rotated at a rate different from that of its core. In more recent times this idea has been revived by Sir F. J. Evans (1878) to account for the secular variations in the declination of the magnetic needle.

Clairault's celebrated theorem (1743), on which Laplace based the most long-lived among many cosmogonies, gave us a globe of molten matter surrounded by a solid crust. Hopkins demanded a globe solid to the core, and, though his arguments were considered to be unsound, his conclusions have been revived on other grounds; while the high rigidity of the Earth as a body has been maintained by Lord Kelvin, Sir George Darwin, Professor Newcombe, Dr. Rudski, and especially by the recent observations of Dr. O. Hecker, supplemented by the mathematical reasoning of Professor A. E. H. Love. Hennessy (1886), however, concluded that the astronomical demands could be satisfied by the old-fashioned molten Earth in which the heavier substances conformed to the equatorial belt.

As long ago as 1858 Herbert Spencer suggested that, on account of its temperature being probably above the critical temperature of known elements, the centre of the Earth is possibly gaseous. Late in the 'seventies Dr. Ritter revived the idea of a gaseous core surrounded by a solid crust, and this was modified in 1900 by the Swedish philosopher, Svante Arrhenius, whose globe with a solid crust, liquid substratum, and gaseous core is now a favourite among some geologists.

Wiechert (1897) supposed that the core of the Earth, some 5,000 kilomètres in radius, is composed mostly of iron with a density of 7·8, while this is surrounded by a shell of lithoidal material having a density of about 3·0 to 3·4; and this great contrast in density is about that which distinguishes the iron meteorites generally from those of the stony class. Arrhenius also assumes that iron forms the main part of the central three-quarters, and he shows that this distribution of substance may still be consistent with his theory of a gaseous core; indeed, he not only imagines that the whole of the iron nucleus is gaseous, but also most of the siliceous shell, for he leaves only 5 per cent. of the radius as the depth of the solid and liquid shells combined.

But the variety of ideas does not end with theories on the present constitution of the globe. Poisson required the process of solidification to begin from the centre and to progress outwards, while other mathematicians had been happy with the Leibnitzian *consistentior status* as the first external slaggy crust. Since the days of Laplace all naturalists have been forced to accept the idea of a solar system formed by the cooling and condensation of a spheroidal gaseous nebula; and all except those geologists who have vainly searched for traces of the primeval crust have been happy in this belief.

Recently, however, Dr. F. R. Moulton and Professor T. C. Chamberlin

in America have brought together arguments from different points of view to construct the solar system by the aggregation of innumerable small bodies, 'planetesimals,' which have gathered into knots to form the planets. Thus, the Earth is supposed to have grown gradually by the accretion of meteoritic matter, and even now, although the process has nearly ceased, it receives much meteoritic material from outside.

With the Chamberlin-Moulton theory there must have been a time when the gravity of the Earth was insufficient to hold an atmosphere of any but the heavier gases, such as carbon dioxide; later, the Earth became heavy enough to retain oxygen, then nitrogen, water-vapour, and helium; while even now it may not be sufficiently attractive to prevent the light and agile molecule of hydrogen from flying off into space. With the growth of the young globe, the compression towards the centre produced heat enough to melt the accumulated fragments of meteoritic matter, and the molten material thus formed welled out at the surface. Such volcanic action is supposed to have predominated at the surface until an appreciable atmosphere was formed, and became charged with water, when the now familiar processes of weathering, erosion, and deposition produced the film of 'rust' which geologists know as sedimentary rocks.

With this last addition to the variegated array of theories about the physical condition of the Earth and about its genealogy, the scientific world began again to settle down into serenity, comforted by the happy feeling that all at any rate agree in regarding the Earth as a gradually cooling body, with many millions of years still before it. Then came the discovery of radium, and, with it at first, an assurance that geologists were justified in claiming a long past, to be followed by a longer future than the most optimistic philosopher had dared before to assume with our apparently limited store of Earth-heat. Now, however, Professor Joly warns us that if the deeper parts of the globe contain anything near the proportion of radioactive bodies found by him in the superficial rocks, we may even be tending in the other direction; that, instead of a peaceful cooling, our descendants may have to face a catastrophic heating; the now inconspicuous little body known as the Earth may indeed yet become famous through the Universe as a new star.[2]

To add to the variety of ideas regarding the present state of the Earth's interior, Professor Schwarz, of Grahamstown,[3] concludes that our volcanic phenomena can be accounted for on the assumption that the main mass of the Earth below a superficial layer is cold and solid throughout, being composed, like the meteorites, largely of unaltered ferromagnesian silicates and iron.

Thus, we see, whole fleets of hypotheses have been launched on this sea of controversy: some of the craft have been decoyed by the cipher-signals of the mathematician; some have foundered after bombardment by the heavy missiles classically reserved for use by militant geologists; others, though built in the dockyard of physicists, have suffered from the spontaneous combustion set up by an inadvertent shipment of radium. Still, some of these hypotheses are yet apparently seaworthy, and it may not be unprofitable to compare them with recently acquired data.

The nearest approach to actual observation with regard to the state of the Earth's interior has been obtained by the seismograph, designed to record the movements of seismic waves at great distances from the disturbing earthquake. Some of the waves sent forth from an earthquake-centre travel through the Earth, and some travel around by the superficial crust, the former reaching the distant seismograph before the latter. The seismograph, by its record of the waves that travel *through* the Earth, has thus given a certain amount of information regarding the state of the Earth's interior which R. D. Oldham aptly regards as analogous to that given by the spectroscope[4] with regard to the inaccessible atmosphere of the Sun.

[2] J. Joly, *Radioactivity and Geology*, 1909, pp. 168-172.

[3] E. H. L. Schwarz, *Causal Geology*, 1910.

[4] In his Presidential Address to the Geological Society of London in 1909, Professor W. J. Sollas (*Proc. Geol. Soc.*, 1909, p. lxxxvii) credits H. Benndorf (*Mitth. Geol. Gesellsch.* Wien, I., 1908, 336) with this pretty analogy, but Oldham has the precedence by just two years (*cf. Quart. Journ. Geol. Soc.*, vol. 62, 1906, p. 456).

The existence of two groups of earthquake-waves—those passing through, and those passing near the surface around the Earth—has long been recognised; but R. D. Oldham [5] has shown that the waves passing through the Earth are of two kinds, travelling at two different speeds.

The record on the distant seismograph thus shows three well-marked phases: the first phase, due to waves of compression passing through the Earth's interior; the second phase, due to waves of distortion,[6] also passing through the Earth's interior; and the third phase, recorded by the waves which pass around the arc along the superficial crust.

The third phase is always recorded at a time after the occurrence of the shock proportional to the arcual distance of the recording seismograph from the earthquake centre, the records of several large earthquakes showing an average speed for the waves of about three kilomètres per second. The rates of propagation of the waves giving the first and second phases are both much greater than of those forming the third phase; and up to an arcual distance of about 120° from the earthquake's centre the rate of their propagation increases with the distance. It is thus assumed that the waves giving rise to the first and second phases in each distant seismographic record, by following approximately along the chord of the arc between the place of origin and the instrument, pass through deeper layers of the Earth when the seismograph is farther away, the material at greater depths being presumably more elastic as well as denser.

But Oldham [7] has shown that when the seismograph is as much as 150° from the earthquake centre there is a remarkable decrease in the mean apparent rate of propagation of the waves giving the second phase in the record, from over six to about four and a half kilomètres per second. There is also a drop, although not nearly so marked, in the apparent speed of the waves of the first phase when transmitted to a seismograph 150° or more distant from the earthquake origin. Oldham concludes that this decrease of apparent rate for waves travelling through the Earth to places much more than 120° distant is due to their passing into a central core, four-tenths of the radius in thickness, composed of matter which transmits the waves at a markedly slow speed. Thus the earthquake waves which emerge at a distance not greater than 120° from their origin do not enter this central core, while those which pass into the Earth to a greater depth than six-tenths of the radius are supposed to be refracted on entering, and again on leaving the postulated core, in which the rate of transmission of an elastic wave of distortion is very much slower than in the main mass of the Earth around. In consequence of the refraction of these waves on passing through the central core, places situated at about 140° from an earthquake origin should be in partial shadow, due to the great dispersion of the distortional waves, and the few records made so far by seismographs thus situated with regard to great earthquakes show that there is either no, or at most a doubtful, record for the second phase, which is known to be due to the so-called distortional waves.

Oldham's deductions are based confessedly on a small number of earthquake records—he considered fourteen examples only—but the conclusions based on a small number of trustworthy records, from which variations due to the different methods of marking the phases are eliminated, are more reliable than those for which there are imperfect distant records as well as doubts regarding the exact times of the disturbances. If these observations, however, be confirmed by further records, we are justified in assuming that below the heterogeneous crust there is a thick shell of elastic material, fairly homogeneous to about six-tenths of the radius, surrounding a central core, four-tenths in thickness, which possesses physical properties utterly unlike those of the outer layers; for in this core the 'distortional' waves are either damped completely or are transmitted at very much lower speeds than in the shell.

[5] *Phil. Trans.*, Ser. A., vol. exciv. (1900), pp. 135-74.

[6] There is more complete agreement regarding the fact that two distinct sets of waves give rise to the so-called preliminary tremors indicated by a seismographic record than about the nature of the waves. *Confer.* R. D. Oldham, *Phil. Trans.*, *loc. cit.*, and O. Fisher, *Proc. Cambr. Phil. Soc.*, vol. xii. pp. 354-361.

[7] *Quart. Journ. Geol. Soc.*, vol. 62, pp. 456-475 (1906).

One cannot consider this interesting inference from the seismographic data without being reminded of the contention of Ritter, Arrhenius, and Wilde regarding the possibility of a persistent gaseous core still above the critical temperature of the substances of which it is composed. According to Ritter,[8] the gaseous core is surrounded by a solid shell. Dr. Wilde [9] postulates the existence of a liquid substratum and a gaseous core within a solid crust, the two outer shells having a thickness that is 'not very considerable.' Arrhenius assumes from purely physical considerations that the solid crust is only about twenty-five miles thick, that below this it is possibly in a molten condition for about a hundred and fifty miles, and that the rest is a gas largely composed of iron under a pressure so great that its compressibility is not much less than that of steel.

The whole of these conclusions, being based on assumptions regarding the physical properties of matter under conditions of temperature and pressure that are well beyond those of actual experience, must be put on a plane of science well below that occupied by the investigations initiated by Oldham, who opens up a line of research in which, as said before, the seismograph may justifiably be compared with the spectroscope as an instrument for observing some inaccessible regions of Nature.

The mathematician apparently finds it just as easy to prove that the Earth is solid throughout as to show by extrapolation from known physical values that it must be largely gaseous. As Huxley said in his Presidential Address to the Geological Society in 1869, the mathematical mill is a mill which grinds you stuff of any degree of fineness, but, nevertheless, it can grind only what is put into it; and the seismograph thus offers a new source of substantial grist. Now that it is fairly certain that some of the earthquake-waves pass through the deeper parts of the Earth, it is obvious that a fruitful development of science will follow successful efforts to introduce precision in recording, and uniformity of expression in reading, seismographic records.

Oldham [10] has pointed out another way in which analysis of seismographic records may lead to information regarding intra-telluric conditions by comparing the records of waves that pass under the oceanic depressions with those that are sub-continental for the whole or most of their paths. By comparing the records in Europe of the Colombian earthquake of January 31, 1906, with those of the San Francisco quake in the following April, there was a greater interval noticed between the first and second phases of the Californian earthquake - an interval greater than can be accounted for by mere difference of distance between the origin of the shock and the recording instruments. The seismic waves which passed from Colombia to Europe must have travelled under the broadest and deepest part of the North Atlantic basin, while those from California ran under the continent of North America, crossed the North Atlantic not far south of Iceland, and approached Europe from the north-west, the wave paths throughout being under continents or the continental shelf of the North Atlantic. There is thus suggested some difference between the elastic conditions of the sub-oceanic and the sub-continental parts of the crust—a difference which, judging by the particular instances discussed, may extend to a depth of one-quarter of the radius, but is not noticeable in the waves which penetrate to one-third of the radius below the surface.

Obviously these data must be multiplied many times before they can be regarded as a reliable index to a natural law; but it is significant that this

[8] A. Ritter, 'Untersuchungen über die Höhe der Atmosphäre und die Constitution gasformiger Weltkörper,' Wiedemann's *Ann. d. Phys. und Chem.*, vol. v. 405, 543 (1878); vol. vi. 135 (1879); vii. 304 (1879); viii. 157 (1879).

[9] *On the Causes of the Phenomena of Terrestrial Magnetism*, Pamphlet, 1890, p. 2. The idea that the Earth's magnetism is due to the electricity generated by the friction between the shell and the core, rotating with a different motion, was suggested by Dr. Wilde in 1902 (*Mem. Manch. Lit. and Phil. Soc.*, vol. 46, Part IV. p. 8, 1902). A similar suggestion based also on Halley's conception of a separately rotating inner core was made previously by Sir F. J. Evans in 1878 ('Remarkable Changes in the Earth's Magnetism,' *Nature*, vol. xviii. p. 80).

[10] *Quart. Journ. Geol. Soc.*, vol. 63, 344-350 (1907).

indication of a difference between the physical nature of the sub-oceanic and sub-continental parts of the crust is in rough correspondence with the conclusions previously suggested on quite other grounds.

In his Presidential Address to the Geographical Section of the British Association at Dover in 1899, the late Sir John Murray drew attention to the chemical differentiation which has been going on between the continents and the oceans since the processes of weathering and denudation commenced. By these processes the more siliceous and specifically lighter constituents are left behind on the continents, while the heavier bases are carried out to the ocean. It is to this process that Professor T. C. Chamberlin [11] also ascribes the origin of the depressions in which the oceanic waters have accumulated. As a corollary of the planetesimal theory, Chamberlin assumes that water began to be forced out of the porous surface blocks of the accumulated meteoritic material when the Earth's radius was between 1,500 and 1,800 miles shorter than it is now; at that time pools of water began to be formed on the surface, and the atmosphere, just commencing its work, began the operation of leaching the heavier bases out of the highlands. Growth of the world proceeded by the infall of planetesimals, and while those meteorites that fell on the highlands became deprived of their soluble bases, those that fell into the young ocean were merely buried unaltered. Thus, by the time the Earth reached its present size its crust under the oceanic depressions must have developed a chemical composition differing from that under the continents. According to the deduction suggested by Oldham from the seismographic records, there is a noticeable difference in the sub-oceanic areas to depths of between 1,000 and 1,300 miles—a layer in which the followers of Chamberlin's theory might reasonably expect some physical expression of the partially developed chemical differentiation.

The occurrence of denser material below the oceans has, of course, long been assumed from the deflection of the plumb-line, and was accepted by Pratt for his theory of compensation, as well as by Dutton as a wide expression of the theory of isostasy. Chamberlain [12] thus explains the general prevalence of basic lavas in oceanic volcanoes.

The apparent heterogeneity indicated in the outer shell of the Earth to depths of 1,000 miles is naturally in conflict with the assumption that from thirty miles or so down the materials are in a liquid condition; at any rate, the idea conflicts with Fisher's extreme conception of the liquid substratum, in which the fluidity is supposed to be sufficient for the production of convection currents, upwards beneath the oceanic depressions, spreading horizontally towards the continents, and thence downwards to complete the circuit.

The idea that changes of azimuth and of latitude may be brought about by the sliding of the Earth's crust over its core has been put forward more than once to account for the climatic changes of past geological ages—the occurrence of temperate or even warm climates on parts of the crust now within the polar circles, and glacial conditions at the sea-level in countries like India, Australia, Africa, and South America, which are now far from the polar ice-sheets and in some cases near or within the tropics. Professor E. Koken, of Tübingen,[13] in an elaborate memoir entitled 'Indisches Perm und die Permische Eiszeit,' attributes the idea of a sliding crust to Mr. R. D. Oldham; but a similar suggestion was put forward by the late Sir John Evans twenty years before the publication of Mr. Oldham's paper,[14] and when the theory was restated in more precise form, ten years later,[15] it was subjected to mathematical criticism by J. F. Twisden, E. Hill, and O. Fisher.[16]

[11] Chamberlin and Salisbury, *Geology*, vol. ii. 1906, 106-111.

[12] *Geology*, ii. 1906, p. 120.

[13] *N. Jahrb. für Min. u.s.w.*, 1907, 537.

[14] J. Evans, 'On a possible Geological Cause of Changes in the Position of the Axis of the Earth's Crust,' *Proc. Roy. Soc.*, xv. 46 (1866).

[15] J. Evans, Presidential Address, *Proc. Geol. Soc.*, 1876, p. 105.

[16] J. F. Twisden, 'On possible Displacements of the Earth's Axis of figure produced by Elevations and Depressions of her Surface,' *Quart. Journ. Geol. Soc.*, xxxiv. 35 (1877). E. Hill, 'On the possibility of Changes in the Earth's Axis,' *Geol. Mag.*, 1878, 262 and 479. O. Fisher, 'On the possibility of Changes in the Latitude of Places on the Earth's Surface,' *Geol. Mag.*, 1878, pp. 291 and 551.

Sir John Evans suggested that this movement of the crust was inevitable as a consequence of the moulding of the orographical features and consequent redistribution of weights; but Twisden came to the conclusion that the re arrangement of the great inequalities on the Earth's surface would be insufficient to produce any appreciable sliding of the order required to make material differences in the climate of any place.

Oldham,[17] who was writing at the time in the field in India and thus away from literature, put forward the idea in 1886 as an independent thought, and made use of Fisher's new theory regarding the existence of a fluid stratum between the solid crust and the supposed solid core to account for the shifting of places relative to the axis of rotation from the equatorial region even to the polar circles. Oldham drew attention to the recorded small changes of latitude at certain observatories and to the probable changes of azimuth in the Pyramids of Egypt—evidences of a kind which have since been greatly enlarged by the work of Sir Norman Lockyer and others.

The movements assumed to have taken place during the human period are of course small; and to project from them changes as great as the transfer of lands from the polar circle to the tropics has the objection that characterises a surveyor's use of 'unfavourable' triangles in a trigonometrical survey. Before admitting, therefore, that these small changes of latitude and of azimuth may be classed with the palæo-glacialists' evidence as data of the same kind, though so utterly different in magnitude, it is desirable briefly to examine the geological evidence regarding past ice-ages in extra-polar areas.

From the records of ancient glaciations we might omit those of the pre-Cambrian rocks of North Ontario and the pre-Upper Cambrian of Norway, as these areas are nearer the poles than many places which were certainly covered with ice-sheets during the youngest, or often so called Great, Ice Age. But besides these we have evidence of glaciation in the Cambrian or possibly pre-Cambrian rocks of South Australia at a latitude of 35° or less; in South Africa there were two or more distinct glacial periods before Lower Devonian times in slightly lower latitudes; while in China similar records are found among rocks of the Lower Cambrian, or possibly of older age, at a latitude of 31° N.

The glacial boulder-beds found at the base of our great coal-bearing system in India belong to the same stratigraphical horizon as the glacial beds found in South Africa, certain parts of Australia, and in parts of Brazil and São Paulo near or within the southern tropic.

These glacial beds are often referred to in geological literature as Permo-Carboniferous in age; but Professor Koken regarded the formation in India as Permian. Other valuations of palæontological evidence, similar to that relied on by Professor Koken, place these beds at a distinctly lower horizon in the European stratigraphical scale, and recent work by officers of the Geological Survey of India in Kashmir tends to confirm this latter view; we now regard the base of our great coal-bearing system in India—the horizon of the glacial boulder-beds—as not much, if at all, younger than the Upper Coal Measures of Britain.[18] The precise age of the horizon is not very important for our present consideration: the important point is that in or near Upper Carboniferous times a wide-spread glaciation occurred throughout the area now occupied by India, Australia, and South Africa. The records of this great glaciation are thus found stretching northwards beyond the northern as well as southwards beyond the southern tropic.

Now, on the assumption that the cold climate in this region was due to a movement of the crust over the nucleus, Professor Koken has produced an elaborate map of the World, showing the distribution of land and sea during the period, with the directions of ocean-currents and of ice-sheets. The Permian South Pole he places at the point of intersection of the present 20th parallel S. and 80th meridian E.—that is, at a point in the Indian Ocean about equidistant from the glaciated regions of India, Australia, and South Africa. The Permian North Pole is thus forced to take up its position in the centre of Mexico, while the Equator strikes through Russia, Italy, West Africa, down through the South Atlantic and round by Fiji to Vladivostock.

[17] *Geol. Mag.*, 1886, 304.

[18] H. H. Hayden, *Rec. Geol. Surv. Ind.*, vol. xxxvi. p. 23, 1907.

The very precision of this map reduces the theory on which it is based to a condition of unstable equilibrium. If glacial conditions were developed in India, Australia, and South Africa by a 70° movement of the crust, were the movements to and from its assumed position in Permian times so rapid that the glaciation of these widely separated areas appears to be geologically contemporaneous? If such movements had occurred, instead of evidences of glaciation over a wide area at the *same* period, we ought rather to find that the glaciation in each of the widely separated points occurred during distinctly *different* geological periods.

But that is not the only weak spot in the evidence. The Permian (or Permo-Carboniferous) glaciation of Australia took place on the east and south-east of the continent as well as in Western Australia, and the eastern ice-sheets would thus have been active within 30° of Professor Koken's Permian equator. There are still three other serious pieces of colour-discord in this picture. In the State of São Paulo—that is, within Koken's 'Permian' tropics—Dr. Orville Derby has described beds which strikingly recall the features of the Upper Palæozoic glacial beds of India and South Africa. It is possible that these are due to the work of glaciers at a high level; but, since the publication of Professor Koken's memoir, other occurrences of the kind have been described by Dr. I. C. White in different parts of Brazil, and there is a general correspondence between the phenomena in South America and those in the formations of the same age in the Indian, Australian, and African regions.

Then, too, if we accept this expression of the physical geography during Upper Palæozoic times, we must carefully explain away the suspicious breccias and brockrams which have been regarded by many geologists as evidences of a cold climate during Permian times in the Urals, the Thüringerwald, the English Midland and Northern counties, Devonshire and Armagh—places that would lie on or near Koken's 'Permian' equator. Finally, we find the hypothetical Permian North Pole in a locality which has failed to produce any signs of glaciation.

To attempt a discussion of the explanations offered to account for the great Upper Palæozoic glaciation would lead us far from the present theme. The question is raised merely to show that the phenomena are not consistent with the supposed movement of a solid shell over a solid core assisted by an intermediate molten lubricant. Geologists may be compelled to hand back the theory of a molten substratum to the mathematicians and physicists for further repair; but it does not necessarily follow that a foundation theory is unsound merely because it has been overloaded beyond its compressive strength.

The extraordinarily great distances between the areas that show signs of glaciation in Permo-Carboniferous times form a serious stumbling-block to most of the explanations which have hitherto been offered. One is almost tempted in despair even to ask if it is not possible that these fragments of the old Gondwana continent are now more widely separated from one another than they were in Upper Palæozoic times. It is a bold suggestion indeed that one can safely put aside as absurd in geomorphology. There is nothing else apparently left for us but the assumption of a general refrigeration.

The idea of the greater inequalities of the globe being in approximately static equilibrium has been recognised for many years: it was expressed by Babbage and Herschel; it was included in Archdeacon Pratt's theory of compensation; and it was accepted by Fisher as one of the fundamental facts on which his theory of mountain structure rested. But in 1889 Captain C. E. Dutton presented the idea 'in a modified form, in a new dress, and in greater detail'; he gave the idea orthodox baptism and a name, which seems to be necessary for the respectable life of any scientific theory. 'For the condition of equilibrium of figure, to which gravitation tends to reduce a planetary body, irrespective of whether it be homogeneous or not,' Dutton [19] proposed 'the name *isostasy*.' The corresponding adjective would be isostatic—the state of balance between the ups and downs on the Earth.

For a long time geologists were forced to content themselves with the conclusion that the folding of strata is the result of the crust collapsing on a cooling

[19] Dutton, 'On some of the Greater Problems of Physical Geology,' *Bull. Phil. Soc. Wash.*, xi. 53, 1889.

and shrinking core; but Fisher pointed out that the amount of radial shrinking could not account even for the present great surface inequalities of the lithosphere, without regard to the enormous lateral shortening indicated by the folds in great mountain regions, some of which, like the Himalayan folds, were formed at a late date in the Earth's history, folds which in date and direction have no genetic relationship to G. H. Darwin's primitive wrinkles. Then, besides the folding and plication of the crust in some areas, we have to account *for the undoubted stretching which it has suffered in other places*, stretching of a kind indicated by faults so common that they are generally known as normal faults. It has been estimated by Claypole that the folding of the Appalachian range resulted in a horizontal compression of the strata to a belt less than 65 per cent. of the original breadth. According to Heim the diameter of the northern zone of the central Alps is not more than half the original extension of the strata when they were laid down in horizontal sheets. De la Beche, in his memoir on Devon and Cornwall, which anticipated many problems of more than local interest, pointed out that, if the inclined and folded strata were flattened out again, they would cover far more ground than that to which they are now restricted on the geological map. Thus, according to Dutton, Fisher, and others, the mere contraction of the cooling globe is insufficient to account for our great rock-folds, especially great folds like those of the Alps and the Himalayas, which have been produced in quite late geological times. It is possible that this conclusion is in the main true; but in coming to this conclusion we must give due value to the number of patches which have been let into the old crustal envelope—masses of igneous rock, mineral veins and hydrated products which have been formed in areas of temporary stretching, and have remained as permanent additions to the crust, increasing the size and bagginess of the old coat, which, since the discovery of radium, is now regarded as much older than was formerly imagined by non geological members of the scientific world.

The peculiar nature of rock-folds presents also an obstacle no less formidable from a qualitative point of view. If the skin were merely collapsing on its shrinking core we should expect wrinkles in all directions; yet we find great folded areas like the Himalayas stretching continuously for 1,400 miles, with signs of a persistently directed overthrust from the north; or we have folded masses like the Appalachians of a similar order of magnitude stretching from Maine to Georgia, with an unmistakable compression in a north-west to south-east direction. The simple hypothesis of a collapsing crust is thus 'quantitatively insufficient,' according to Dutton, though this is still doubtful, and it is 'qualitatively inapplicable,' which is highly probable.

In addition to the facts that rock-folds are maintained over such great distances and that later folds are sometimes found to be superimposed on older ones, geologists have to account for the conditions which permit of the gradual accumulation of enormous thicknesses of strata without corresponding rise of the surface of deposition.

On the other hand, too, in folded regions there are exposures of beds superimposed on one another with a total thickness of many miles more than the height of any known mountain, and one is driven again to conclude that uplift has proceeded *pari passu* with the removal of the load through the erosive work of atmospheric agents.

It does not necessarily follow that these two processes are the direct result of loading in one case and of relief in the other; for slow subsidence gives rise to the conditions that favour deposition and the uplifting of a range results in the increased energy of eroding streams.

Thus there was a natural desire to see if Dutton's theory agreed with the variations of gravity. If the ups and downs are balanced, the apparently large mass of a mountain-range ought to be compensated by lightness of material in and below it. Dutton was aware of the fact that this was approximately true regarding the great continental plateaux and oceanic depressions; but he imagined that the balance was delicate enough to show up in a small hill-range of 3,000 to 5,000 feet.

The data required to test this theory, accumulated during the triangulation of the United States, have been made the subject of an elaborate analysis by

J. F. Hayford and W. Bowie.[20] They find that, by adopting the hypothesis of isostatic compensation, the differences between the observed and computed deflections of the vertical caused by topographical inequalities are reduced to less than one-tenth of the mean values which they would have if no isostatic compensation existed. According to the hypothesis adopted, the inequalities of gravity are assumed to die out at some uniform depth, called the depth of compensation, below the mean sea-level. The columns of crust material standing above this horizon vary in length according to the topography, being relatively long in highlands and relatively short under the ocean. The shorter columns are supposed to be composed of denser material, so that the product of the length of each column by its mean density would be the same for all places. It was found that, by adopting 122 kilomètres as the depth of compensation, the deflection anomalies were most effectually eliminated, but there still remained unexplained residuals or local anomalies of gravity to be accounted for.

Mr. G. K. Gilbert,[21] who was one of the earliest geologists to turn to account Dutton's theory of isostasy, has recently offered a plausible theory to account for these residual discrepancies between the observed deflections and those computed on the assumption of isostatic compensation to a depth of 122 kilomètres. An attempt had already been made by Hayford and Bowie to correlate the distribution of anomalies with the main features of the geological map and with local changes in load that have occurred during comparatively recent geological times. For example, they considered the possibility of an increased load in the lower Mississippi valley, where there has been in recent times a steady deposition of sediment, and therefore possibly the accumulation of mass slightly in advance of isostatic adjustment. One would expect in such a case that there would be locally shown a slight excess of gravity, but, on the contrary, there is a general prevalence of negative anomalies in this region. In the Appalachian region, on the other hand, where there has been during late geological times continuous erosion, with consequent unloading, one would expect that the gravity values would be lower, as isostatic compensation would naturally lag behind the loss of overburden; this, however, is also not the case, for over a greater part of the Appalachian region the anomalies are of the positive order. Similarly, in the north central region, where there has been since Pleistocene times a removal of a heavy ice-cap, there is still a general prevalence of positive anomalies.

These anomalies must, therefore, remain unexplained by any of the obvious phenomena at the command of the geologist. G. K. Gilbert now suggests that, while it may be true that the product of the length of the unit column by its mean density may be the same, the density variations within the column may be such as to give rise to different effects on the pendulum. If, for instance, one considers two columns of the same size and of exactly the same weight, with, in one case, the heavy material at a high level and in the other case with the heavy material at a low level, the centre of gravity of the former column, being nearer the surface, will manifest itself with a greater pull on the pendulum; these columns would be, however, in isostatic adjustment.[22]

[20] J. F. Hayford, 'The Figure of the Earth and Isostasy,' *U.S. Coast and Geodetic Survey*, Washington, 1909. 'Supplementary Investigation,' Washington, 1910. See also *Science*, New Series, vol. xxxiii., p. 199, 1911. J. F. Hayford and W. Bowie, 'The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity,' *U.S. Coast and Geodetic Survey Special Publication* No. 10, Washington, 1912.

[21] 'Interpretation of Anomalies of Gravity,' *U.S. Geol. Surv. Professional Paper* 85-C, 1913, p. 29.

[22] It is interesting to note that the idea suggested by G. K. Gilbert in 1913 was partly anticipated by Major H. L. Crosthwait in 1912 (*Survey of India, Professional Paper* No. 13, p. 5). Major Crosthwait in discussing the similar gravity anomalies in India remarks parenthetically: 'Assuming the doctrine of isostasy to hold, is it not possible that in any two columns of matter extending from the surface down to the depth of compensation there may be the same mass, and yet that the density may be very differently distributed in the two

Gilbert's hypothesis thus differs slightly from the conception put forth by Hayford and Bowie; for Gilbert assumes that there is still appreciable heterogeneity in the more deep-seated parts of the Earth, while Hayford and Bowie's hypothesis assumes that in the nuclear mass density anomalies have practically disappeared, and that there is below the depth of compensation an adjustment such as would exist in a mass composed of homogeneous concentric shells.

In order to make the Indian observations comparable to those of the United States as a test of the theory of isostasy, Major H. L. Crosthwait[23] has adopted Hayford's system of computation and has applied it to 102 latitude stations and 18 longitude stations in India. He finds that the unexplained residuals in India are far more pronounced than they are in the United States, or, in other words, it would appear that isostatic conditions are much more nearly realised in America than in India.

The number of observations considered in India is still too small for the formation of a detailed map of anomalies, but the country can be divided into broad areas which show that the mean anomalies are comparable to those of the United States only over the Indian peninsula, which, being a mass of rock practically undisturbed since early geological times, may be regarded safely as having approached isostatic equilibrium. To the north of the peninsula three districts form a wide band stretching west-north-westwards from Calcutta, with mean residual anomalies of a positive kind, while to the north of this band lies the Himalayan belt, in which there is always a large negative residual.

Colonel Burrard[24] has considered the Himalayan and Sub-Himalayan anomalies in a special memoir, and comes to the conclusion that the gravity deficiency is altogether too great to be due to a simple geosynclinal depression filled with light alluvium such as we generally regard the Gangetic trough to be. He suggests that the rapid change in gravity values near the southern margin of the Himalayan mass can be explained only on the assumption of the existence of a deep and narrow rift in the sub-crust parallel to the general Himalayan axis of folding. A single large rift of the kind and size that Colonel Burrard postulates is a feature for which we have no exact parallel; but one must be careful not to be misled by the use of a term which, while conveying a definite mental impression to a mathematician, appears to be incongruous with our geological experience. There may be no such thing as a single large rift filled with light alluvial material, but it is possible that there may still be a series of deep-seated fissures that might afterwards become filled with mineral matter.

With this conception of a rift or a series of rifts, Colonel Burrard is led to reverse the ordinary mechanical conception of Himalayan folding. Instead now of looking upon the folds as due to an overthrust from the north, he regards the corrugations to be the result of an under-creep of the sub-crust towards the north. Thus, according to this view, the Himalaya, instead of being pushed over like a gigantic rock-wave breaking on to the Indian *Horst*, is in reality being dragged away from the old peninsula, the depression between being filled up gradually by the Gangetic alluvium. So far as the purely stratigraphical features are concerned, the effect would be approximately the same whether there is a superficial overthrust of the covering strata or whether there is a deep-seated withdrawal of the basement which is well below the level of observation.

Since the Tibetan expedition of ten years ago we have been in possession of definite facts which show that to the north of the central crystalline axis of the Himalaya there lies a great basin of marine sediments forming a fairly complete record from Palæozoic to Tertiary times, representing the sediments

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columns? These two columns, though in isostatic equilibrium, would act differently on the plumb-line owing to the unequal distribution of mass.

'The drawback to treating this subject by hard and fast mathematical formulæ is that we are introducing into a discussion of the constitution of the earth's crust a uniform method when, in reality, probably no uniformity exists.'

[23] *Survey of India, Professional Paper* No. 13, 1912.

[24] *Ibid.* No. 12, 1912.

which were laid down in the great central Eurasian ocean to which Suess gave the name *Tethys*. We have thus so far been regarding the central crystalline axis of the Himalaya as approximately coincident with the old northern coast-line of Gondwanaland; but, if Colonel Burrard's ideas be correct, the coast-line must have been very much further to the south before the Himalayan folding began.

Representing what the Geological Survey of India regards as the orthodox view, Mr. H. H. Hayden [25] has drawn attention to some conclusions which, from our present geological knowledge, appear to be strange and improbable in Colonel Burrard's conclusions, and he also offers alternative explanations for the admitted geodetic facts. Mr. Hayden suggests, for instance, that the depth of isostatic compensation may be quite different under the Himalayan belt from that under the regions to the south. His assumptions, however, in this respect are, as pointed out by Colonel G. P. Lenox Conyngham,[26] at variance with the whole theory of isostasy. Mr. Hayden then suggests that most of the excessive anomalies would disappear if we took into account the low specific gravity of the Sub-Himalayan sands and gravels of Upper Tertiary age as well as of the Pleistocene and recent accumulations of similar material filling the Indo-Gangetic depression. It would not be at all inconsistent with our ideas derived from geology to regard the Gangetic trough as some three or four miles deep near its northern margin, thinning out gradually towards the undisturbed mass of the Indian peninsula, and Mr. R. D. Oldham,[27] with this view, has also calculated the effect of such a wedge of alluvial material of low specific gravity, coming to the conclusion that the rapid change in deflection, on passing from the Lower Himalaya southward towards the peninsula, can mainly be explained by the deficiency of mass in the alluvium itself.

It is obvious that, before seeking for any unusual cause for the gravity anomalies, we ought to take into account the effect of this large body of alluvium which lies along the southern foot of the range. It is, however, by no means certain that a thick mass of alluvial material, accumulated slowly and saturated with water largely charged with carbonate of lime, would have a specific gravity so appreciably lower than that of the rocks now exposed in the main mass of the Himalaya as to account for the residual anomalies. Some of the apparent deficiency in gravity is due to this body of alluvium, but it will only be after critical examination of the data and more precise computation that we shall be in a position to say if there is still room to entertain Colonel Burrard's very interesting hypothesis.

By bringing together the geological and geodetic results we notice five roughly parallel bands stretching across northern India. There is (1) a band of abnormal high gravity lying about 150 miles from the foot of the mountains, detected by the plumb-line and pendulum; (2) the great depression filled by the Gangetic alluvium; (3) the continuous band of Tertiary rock, forming the Sub-Himalaya, and separated by a great boundary overthrust from (4) the main mass of the Outer and Central Himalaya of old unfossiliferous rock, with the snow-covered crystalline peaks flanked on the north by (5) the Tibetan basin of highly fossiliferous rocks formed in the great Eurasian mediterranean ocean that persisted up to nearly the end of Mesozoic times.

That these leading features in North India can hardly be without genetic relationship one to another is indicated by the geological history of the area. Till nearly the end of the Mesozoic era the line of crystalline, snow-covered peaks now forming the Central Himalaya was not far from the shore-line between Gondwanaland, stretching away to the south, and Tethys, the great Eurasian ocean. Near the end of Mesozoic times there commenced the great outwelling of the Deccan Trap, the remains of which, after geological ages of erosion, still cover an area of 200,000 square miles, with a thickness in places of nearly 5,000 feet. Immediately after the outflow of this body of basic lava, greater in mass than any known eruption of the kind, the ocean flowed into North-West India and projected an arm eastwards to a little beyond the point

[25] *Rec. Geol. Surv. Ind.*, vol. xliii. part 2, p. 138, 1913.
[26] *Records of the Survey of India*, vol. v. p. 1.
[27] *Proc. Roy. Soc.*, Series A, vol. 90, p. 32, 1914.

at which the Ganges now emerges from the hills. Then followed the folding movements that culminated in the present Himalayan range, the elevation developing first on the Bengal side, and extending rapidly to the north west until the folds extended in a great arc for some 1,400 miles from south-east to north-west.

New streams developed on the southern face of the now rising mass, and although the arm of the sea that existed in early Tertiary times became choked with silt, the process of subsidence continued, and the gradually subsiding depression at the foot of the hills as fast as it developed became filled with silt, sand, gravel, and boulders in increasing quantities as the hills became mountains and the range finally reached its present dimensions, surpassing in size all other features of the kind on the face of the globe.

Now, it is important to remember that for ages before the great outburst of Deccan Trap occurred there was a continual unloading of Gondwanaland, and a continual consequent overloading of the ocean bed immediately to the north; that this process went on with a gradual rise on one side and a gradual depression on the other; and that somewhere near and parallel to the boundary line the crust must have been undergoing stresses which resulted in strain, and, as I suggest, the development of those fissures that let loose the floods of Deccan Trap and brought to an end the delicate isostatic balance.

During the secular subsidence of the northern shore line of Gondwanaland, accompanied by the slow accumulation of sediment near the shore and the gradual filing away of the land above sea-level, there must have been a gradual creep of the crust in a northerly direction. Near the west end of the Himalayan arc this movement would be towards the north-west for a part of the time; at the east end the creep would be towards the north-north-east and north-east. Thus there would be a tendency from well back in Palæozoic times up to the end of the Cretaceous period for normal faults—faults of tension—to develop on the land, with a trend varying from W.S.W.–E.N.E. to W.N.W.–E.S.E. across the northern part of Gondwanaland. We know nothing of the evidence now pigeon-holed below the great mantle of Gangetic alluvium, while the records of the Himalayan region have been masked or destroyed by later foldings. But in the stratified rocks lying just south of the southern margin of the great alluvial belt we find a common tendency for faults to strike in this way across the present Peninsula of India. These faults have, for instance, marked out the great belt of coalfields stretching for some 200 miles from east to west in the Damuda valley. On this, the east side of India, the fractures of tension have a general trend of W.N.W.–E.S.E. We know that these faults are later than the Permian period, but some of them certainly were not much later.

If now we go westwards across the Central Provinces and Central India and into the eastern part of the Bombay Presidency, we find records of this kind still more strikingly preserved; for where the Gondwana rocks, ranging from Permo-Carboniferous to Liassic in age, rest on the much older Vindhyan series, we find three main series of these faults. One series was developed before Permo-Carboniferous times; another traverses the lower Gondwanas, which range up to about the end of Permian times; while the third set affects the younger and Upper Gondwanas of about Rhætic or Liassic age. Although the present topography of the country follows closely the outlines of the geological formations, it is clear from the work of the Geological Survey of India that these outlines were determined in Mesozoic times, and that the movements which formed the latest series of faults were but continuations of those which manifested themselves in Palæozoic times. According to Mr. J. G. Medlicott, the field data showed 'that a tendency to yield in general east and west or more clearly north-east and south-west lines existed in this great area from the remote period of the Vindhyan fault.' [28] The author of the memoir and map on this area was certainly not suspicious of the ideas of which I am now unburdening my mind; on the contrary, he attempted and, with apologies, failed to reconcile his facts to views then being pushed by the weight of 'authority' in Europe. This was not the last time that facts established in India were found (to use a field-geologist's term) unconformably to lie on a basement of

[28] *Mem. Geol. Surv. Ind.*, vol. ii. 1860, part 2, p. 256.

geological orthodoxy as determined by authority in Europe. It is important to notice that the series of faults referred to in the central parts of India are not mere local dislocations, but have a general trend for more than 250 miles.

A fault must be younger, naturally, than the strata which it traverses, but how much younger can seldom be determined. Intrusive rocks of known age are thus often more useful in indicating the age of the fissures through which they have been injected, and consequently the dykes which were formed at the time of the eruption of the great Deccan Trap give another clue to the direction of stresses at this critical time, that is towards the end of the Cretaceous period, when the northerly creep had reached its maximum, just before Gondwanaland was broken up. If, now, we turn to the geological maps of the northern part of Central India, the Central Provinces, and Bengal, we find that the old Vindhyan rocks of the Narbada valley were injected with hundreds of trap-dykes which show a general W.S.W.–E.N.E. trend, and thus parallel to the normal tension faults, which we know were formed during the periods preceding the outburst of the Deccan Trap. This general trend of faults and basic dykes is indicated on many of the published geological maps of India covering the northern part of the peninsula, including Ball's maps of the Ramgarh and Bokaro coalfields [29] and of the Hutar coalfield,[30] Hughes' Rewa Gondwana basin,[31] Jones' southern coalfields of the Satpura basin,[32] and Oldham's general map of the Son Valley.[33]

We see, then, that the development of fissures with a general east-west trend in the northern part of Gondwanaland culminated at the end of the Cretaceous period, when they extended down, probably, to the basic magma lying below the crust either in a molten state, or in a state that would result in fluxion on the relief of pressure. That the molten material came to the surface in a superheated and liquid condition is shown by the way in which it has spread out in horizontal sheets over such enormous areas. Throughout this great expanse of lava there are no certain signs of volcanic centres, no conical slopes around volcanic necks; and one might travel for more than 400 miles from Poona to Nagpur over sheets of lava which are still practically horizontal. There is nothing exactly like this to be seen elsewhere to-day. The nearest approach to it is among the Hawaiian calderas, where the highly mobile basic lavas also show the characters of superfusion, glowing, according to J. D. Dana,[34] with a white heat, that is, at a temperature not less than about 1,300°C.

Mellard Reade has pointed out that the Earth's crust is under conditions of stress analogous to those of a bent beam, with, at a certain depth, a 'level of no strain.' Above this level there should be a shell of compression, and under it a thicker shell of tension. The idea has been treated mathematically by C. Davison, G. H. Darwin, O. Fisher, and M. P. Rudski, and need not be discussed at present. Professor R. A. Daly has taken advantage of this view concerning the distribution of stresses in the crust to explain the facility for the injection of dykes and batholiths from the liquid, or potentially liquid, gabbroid magma below into the shell of tension.[35] He also shows that the injection of large bodies of basic material into the shell of tension tends on purely mechanical grounds to the formation of a depression, or geosyncline. If this be so, are we justified in assuming that the heavy band following the southern margin of the Gangetic geosyncline is a 'range' of such batholiths? The idea is not entirely new; for O. Fisher made the suggestion more than twenty years ago that the abnormal gravity at Kalianpur was due to 'some peculiar influence (perhaps of a volcanic neck of basalt).'[36]

[29] *Mem. Geol. Surv. Ind.*, vol. vi. part 2.
[30] *Ibid.*, vol. xv.
[31] *Ibid.*, vol. xxi. part 3.
[32] *Ibid.*, vol. xxiv.
[33] *Ibid.*, vol. xxxi. part 1.
[34] *Characteristics of Volcanoes*, 1891, p. 200.
[35] R. A. Daly, 'Abyssal Igneous Injection as a Causal Condition and as an Effect of Mountain-building,' *Amer. Journ. Sci.*, xxii. Sept. 1906, p. 205.
[36] *Physics of the Earth's Crust*, 2nd ed., 1889, p. 216.

Daly's suggestion, however, taken into account with the history of Gondwanaland, may explain the peculiar alignment of the heavy subterranean band, parallel to the Gangetic depression and parallel to the general trend of the peninsular tension-faults and fissures that followed the unloading of Gondwanaland and the heavy loading of the adjoining ocean bed along a band roughly parallel to the present Himalayan folds.

R. S. Woodward objected that isostasy does not seem to meet the requirements of geological continuity, for it tends rapidly towards stable equilibrium, and the crust ought therefore to reach a stage of repose early in geologic time.[37] If the process of denudation and rise, with adjoining deposition and subsidence, occurred on a solid globe, this objection might hold good. But it seems to me that the break-up of Gondwanaland and the tectonic revolutions that followed show how isostasy can defeat itself in the presence of a sub-crustal magma actually molten or ready to liquefy on local relief of pressure. It is possible that the protracted filing off of Gondwanaland brought nearer the surface what was once the local level of no-strain and its accompanying shell of tension.

The conditions existing in northern Gondwanaland before late Mesozoic times must have been similar to those in south-west Scotland before the occurrence of the Tertiary eruptions, for the crust in this region was also torn by stresses in the S.W.–N.E. direction with the formation of a remarkable series of N.W.–S.E. dykes which give the one-inch geological maps in this region a regularly striped appearance.

There is no section of the Earth's surface which one can point to as being now subjected to exactly the same kind and magnitude of treatment as that to which Gondwanaland was exposed for long ages before the outburst of the Deccan Trap; but possibly the erosion of the Brazilian highlands and the deposition of the silt carried down by the Amazon, with its southern tributaries, and by the more eastern Araguay and Tocantins, may result in similar stresses which, if continued, will develop strains, and open the way for the subjacent magma to approach the surface or even to become extravasated, adding another to the small family of so-called fissure-eruptions.

The value of a generalisation can be tested best by its reliability as a basis for prediction. Nothing shows up the shortcomings of our knowledge about the state of affairs below the superficial crust so effectually as our inability to make any useful predictions about earthquakes or volcanic eruptions. For many years to come in this department of science the only worker who will ever establish a claim to be called a prophet will be one in Cicero's sense—'he who guesses well.'

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *The Geology of Victoria.* *By* Professor ERNEST W. SKEATS, *D.Sc.*

2. *Exhibition of a Series of Lantern Slides illustrating Desert Scenery and Denudation.* *By* Dr. JOHANNES WALTHER.

Every climatic region is characterised by a different type of disintegration and denudation of soft or softened rock by the agents of erosion. In the nival region a cover of snow protects the surface of the earth during a long period of the year.

In the humid zone and also in the equatorial pluvial region the soil is over-

[37] 'Address to the Sect. of Mathematics and Astronomy of the Amer. Assoc.,' 1889. *Smithsonian Report*, 1890, p. 196.

grown by a network of roots and rootlets of millions of plants, which bind together the small particles and protect them against wind and running water.

In arid regions, where the rain is not sufficient to form perennial rivers, and where the vegetation forms isolated patches in the barren country, every particle of soft or disintegrated rock is quickly taken away by the wind or the occasional rainfall. Therefore the general denudation of the land is very powerful. The Egyptian monuments, exposed during 4,000 years to the disintegrating and denuding powers of the desert, offer beautiful examples of the different kinds of dry disintegration, and many of them show very clearly also the transporting effect of the wind.

3. *The Climatic Conditions of the Early Pre-Cambrian. By* Professor A. P. Coleman, *F.R.S.*

Our knowledge of the later Pre-Cambrian permits us to speak of desert conditions in the Keweenawan or Torridonian and of an ice age followed by a cool climate in the Huronian, but little evidence has been given as to earlier climates. Recent work in Canada shows that the Sudbury series, of Pre-Laurentian age and very much older than the Huronian, includes all types of sediments, often well enough preserved to show cross bedding, ripple marks, and annual layers indicating the change of seasons. They must have been formed near the margin of a continent where granites weathered under a cool and moist climate. They seem to be delta materials deposited by great rivers.

The highly metamorphosed sediments of the still older Grenville and Keewatin series (Lewisian?) have lost their original structures, but the gneisses, quartzites, and marbles must have been clay, sand, and limestone in the beginning, and the graphite may have originated in plants. Land surfaces must have been attacked by water and air to produce these materials, and there is no evidence that the climate was hot. These are the earliest-known formations, so that air and water worked in the usual way at the beginning of recorded geological time.

4. *Victorian Graptolites. By* T. S. Hall, *M.A., D.Sc.*

The Silurian and Ordovician graptolite-bearing rocks of Victoria occupy about 20,000 square miles, and over a hundred species have been recorded.

Very little is known of the Silurian. The Ordovician is divided into Upper and Lower, but probably represents a continuous series. The Upper is characterised by the presence of Dicranograptidæ. No zonal work has been done in the field, though collections yielding about fifty recorded species have been made.

Four divisions are recognised in the Lower Ordovician, namely, Darriwillian, Castlemainian, Bendigonian, and Lancefieldian, at the base. There are several subdivisions of these formations. The characters were briefly indicated in the 'Geological Magazine' by the author in 1899. Subsequent work by T. S. Hart, F.G.S., at Daylesford has confirmed the sequence established. Large collections made by the Survey at many localities have somewhat extended our knowledge of the fauna and its distribution, but without adding any features of great importance.

The Upper Ordovician ranges north from Eastern Victoria for 300 miles into New South Wales. In New Zealand Lancefieldian occurs at Preservation Inlet, and two Castlemaine zones occur as well. It is probable that the Victorian sequence, and not the British as stated, will be found.

Broadly, the sequence of Australian graptolites agrees with the European, but in details is closer to that of New York, as Ruedemann has pointed out. The important differences in the range of *Didymograptus bifidus*, *D. caduceus*, *D. nicholsoni*, *Loganograptus*, *Clonograptus rigidus*, and some other genera and species negative the idea that graptolite zones are world-wide, and as no one believes that all genera and species originated in one locality and radiated thence this is what we should expect.

5. *On the Tertiary Alkali Rocks of Victoria.*
By Professor Ernest W. Skeats, *D.Sc.*

From Mount Leinster in Benambra, Frenchman's Hill near Omeo, and Noyang in Dargo, three areas in Eastern Victoria, the late Dr. Howitt (1) described igneous rocks which belong to the alkali series. They were all regarded by Howitt as of Palæozoic age. The age of the rocks of Noyang, which consist mainly of intrusions and lava-flows of quartz-ceratophyre, has not been closely investigated and may be Palæozoic. Recent work (2), however, has shown, especially in the case of the Omeo rocks, that they are probably of mid- or even of late-Tertiary age. The alkali rocks of Frenchman's Hill, described by Howitt as intrusive orthophyres, consist really in the main of lava-flows of anorthoclase trachyte which has a very scoriaceous margin to the flows. There is a central plug of a coarser quartz-bearing rock allied to sölvsbergite and a more or less radial system of dykes which are principally trachytic in character. Some, however, contain quartz, one at least is a bostonite, and six or seven prove to be dykes of nepheline-phonolite. The district is one which has been affected by a succession of elevatory movements of the plateau type since the mid-Tertiary period, and, according to Griffith Taylor (3), a more or less meridional Senkungsfeld runs through the Omeo district a few miles east of Frenchman's Hill. The rocks of Mount Leinster in Benambra consist principally of sölvsbergites, bostonites, and pyroclastic rocks of alkali trachyte. Petrologically and chemically many of the rocks of Mount Leinster and of Frenchman's Hill closely resemble some of the alkali rocks of Mount Macedon, and, like them, are probably of mid-Tertiary age. The district has been elevated at intervals during the Tertiary period, but physiographically has not been closely studied.

About fourteen miles north-east from Mansfield in north-central Victoria and about three miles from Tolmie, in the Tolmie Highlands, there occurs a volcanic hill, known locally as Gallows Hill, which has recently been shown to consist of a volcanic centre of probably late Tertiary age and to consist of lava-flows of nepheline-phonolite. From a locality near Barwite, east of Mansfield, another nepheline-phonolite has been found, but its field relations are at present uncertain and no account of either of these rocks has yet been published. Fenner (4) has recently shown that block elevation and depression have affected the Mansfield area in recent geological times, and that Gallows Hill lies near one of the fault scarps.

The best-known area of alkali rocks in Victoria is the Mount Macedon district, about forty miles north-west of Melbourne (5). The series is of mid-Tertiary to late-Tertiary age, and the rock sequence from below upwards, while not always demonstrable, appears to be as follows:—Anorthoclase trachyte, sölvsbergite, anorthoclase basalt, macedonite, woodendite, anorthoclase-olivine-trachyte, olivine-anorthoclase-trachyte, limburgite. Immediately succeeding these alkali rocks come lava-flows of normal basalt and of andesitic basalt. The new types macedonite and woodendite contain over 1 per cent. of P_2O_5, and are related to the orthoclase-basalts and to the mugearites.

While this part of Victoria shows evidence by the existence of more than one elevated peneplain of successive movements of the plateau type, no definite evidence of faulting or differential movement has been recognised in the district. In the western district of Victoria more or less extensive lava-flows of anorthoclase-trachyte occur near Coleraine, Carapook, &c. (6). Generally the trachytes appear to be older than the newer basalts, but near Coleraine a dyke of trachyte penetrates a small hill composed of a basic rock resembling olivine-basalt, while at the Hummocks north of Casterton another trachyte dyke similarly penetrates a vent or small flow of olivine-basalt. Among the ejected blocks from the earlier members of the Pleistocene newer basalts of Lake Bullenmerri, near Camperdown, are some consisting of essexite and containing analcite. In the western district of Victoria clear evidence of comparatively recent elevatory movements is noticeable. No definite faults have yet been proved, however, and the normal basalts are much more widely spread than the alkali rocks. In view of Harker's generalisation as to the close correspondence between the occurrence of alkali rocks and elevatory movements of the plateau type, generally accompanied by faulting, the above reference to earth movements is pertinent.

Practically no folding movements are known among the Tertiary rocks of Victoria, while plateau movements, generally of elevation, sometimes of depression and accompanied by faulting, are widespread. Near Omeo and Mansfield, where faulting has been demonstrated or inferred, the highly alkaline types of nepheline-phonolite are developed, but the widespread plateau movements in Victoria are more specially associated with the occurrence of the normal basalts. The alkali trachytes and allied rocks are intercalated between an older and a newer basalt series, are developed only sporadically at certain centres, and as at Macedon are closely associated in the field with the newer basalts as rocks of slightly greater antiquity but belonging to the same volcanic period.

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(5) Gregory, J. W. 'Proc. Roy. Soc. of Vict.,' vol. xxv. N.S., 1901.
Skeats, E. W., and Summers, H. S. 'Geol. Surv. of Vict.' Bulletin No. 24, 1912.
(6) Summers, H. S. Aust. Assoc. for Adv. of Science, Sydney, 1911.
Dennant, J. Aust. Assoc. for Adv. of Science, Adelaide, 1893.
Hogg, E. 'Proc. Roy. Soc. Vict.,' vol. xii. N.S., 1899.

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6. *On the Origin and Relationship of the Victorian Kainozoic Alkali Rocks.* By H. S. Summers, *D.Sc.*

Alkali rocks of Kainozoic age occur in Victoria in the Macedon District, near Coleraine and Carapook in the Western District, and in the neighbourhood of Omeo and Mansfield in North-Eastern Victoria. Ejected blocks from the volcanoes near Camperdown have been described as essexite, and a similar type, also probably ejected, has been found near Kyneton. With the exception of the occurrences of Omeo and Mansfield all these alkali rocks are closely associated with the Upper Kainozoic calcic basalts, and the field relations are such that there is little doubt that the alkali rocks and the basalts are genetically related.

Numerous analyses (mainly unpublished) have been made of Victorian basalts, and these show that they are fairly normal in composition, and consequently should belong to Harker's Calcic or Pacific Branch of Igneous rocks, whereas the sölvsbergites, trachytes, &c., of Macedon, the phonolites of Omeo and Mansfield, the essexites (?) of Camperdown and Kyneton, and the trachytes and anorthoclase-basalts of the Coleraine area must be placed in the Alkali or Atlantic Branch.

It follows then that the evidence of the Victorian Kainozoic rocks does not support Harker's generalisation on Petrographic Regions.

A number of first-class analyses has been made of the principal types of the Macedon series, and variation diagrams based on these analyses have been drawn. (See 'Bulletin of the Geol. Survey of Victoria,' No. 24, 1912, and 'Proceedings of the Royal Society of Victoria,' vol. xxvi. (N.S.), pt. ii. 1914.)

It was found that by re-calculating the analyses to 100 per cent. with the water omitted and the ferric oxide reduced to ferrous, the curves obtained were better than those plotted from the original analyses.

Certain of the analyses did not conform to the curves, and at first these were regarded as representing hybrid types, but additional work showed that they represented complementary types and resulted from the splitting up of a magma instead of the mixing of magmas.

Some analyses have been made of the alkali rocks from other Victorian areas, but not a sufficient number to show the relationship of the various types to one another.

The conclusions are that the Kainozoic alkali rocks of Victoria are derived from the calcic basalts by differentiation, giving rise to several lesser magma reservoirs.

In the case of the Macedon magma further differentiation took place and a series of lavas was extruded which in general showed a serial relationship, but some complementary to one another.

TUESDAY, AUGUST 18.

The following Papers were read :—

1. *The Permian Breccia of the Midland Counties of Britain, a Desert Formation.* By H. T. Ferrar, *M.A., F.G.S.*[1]

During the meeting of the Association at Birmingham last year members of this Section had an ample opportunity for visiting the chief exposures of the so-called Permian breccia of the midland counties of England. This deposit may be briefly described as a mass of sandstones and marls with occasional sheets of angular breccia, the latter consisting in a large measure of volcanic rocks, grits, slates, and limestones which can be identified with rocks on the borders of Wales. The organic remains which have been recorded are few, but such as occur are indicative chiefly of terrestrial surfaces.

The origin of the breccia has given rise to many speculations, amongst which may be mentioned :—

(1) Murchison (1839) regarded it as a volcanic or trappoid breccia marking the position of underground masses of volcanic rocks hidden under a cover of their own fragments.

(2) Ramsay (1855) ascribed its origin to the existence of glacial conditions in Permian times.

(3) Geikie (1892) says with regard to Scotland that the breccia has evidently accumulated in small lakes or narrow fiords during periods of great and rapid denudation following uplift of the Upper Carboniferous rocks.

(4) Bonney (1902) concludes that breccias are usually indicative of continental conditions, but that glaciers are necessary for the transport of the larger boulders.

(5) Lapworth (1912) holds that they are the memorials of local Alpine conditions.

In Egypt a chain of fold mountains forms the watershed between the Nile and the Red Sea, and the mountains are intersected and drained by steep-sided gorges or wadis. The climate is arid with occasional heavy thunderstorms causing temporary torrents, which sweep forward all rock material loosened during the prevailing dry climate. The wadi beds receive continuously a fresh supply of angular débris shed from the adjacent bare hillsides, and any fragments which may have become rounded or subangular are often shattered before the next flood sweeps them forward another stage on their journey towards a more permanent resting-place, namely, the alluvial plain at the wadi-mouth. Blocks slipping down the bare hillsides become scratched or they may be scratched by mutual impact during a sudden rush of flood-water. Great blocks are often carried fifty or one hundred miles down the wadi channels, and the agency of ice need not be invoked to explain their transport.

The valley-fill of most wadis in the Eastern Desert of Egypt is an unconsolidated breccia so similar to the breccia exposed on Ley Hill, near Birmingham, that there is little room for doubt that the two originated under similar climatic conditions.

[1] By permission of the Director-General, Egyptian Survey Department.

2. *Note on the Occurrence of Loess-deposits in Egypt and its Bearing on Change of Climate in recent Geological Times.*[1] *By* H. T. Ferrar, *M.A., F.G.S.*

At a recent meeting of the Association Dr. Hume and Mr. Craig submitted the view that there had been no change, except that of gradual desiccation, in recent geological times in Egypt. Since their paper was published, evidence that the change of climate has not been uniform has been recorded from neighbouring countries. The following short paper is intended to show how æolian desertic deposits may be interstratified between freshwater beds without any change of climate.

In the northern delta of Egypt are great stretches of flat land a few feet above sea-level. These areas are covered by ordinary Nile alluvium and remain damp during the winter months but dry in summer. Owing to the evaporation which takes place during the spring and early summer, soluble salts accumulate at or near the surface of the soil rendering it incoherent and powdery. Winds are now able to lift and transport this material until it is arrested by the roots of halophyte plants or other obstacles. Here also are deposited the dead shells of helices, and occasionally also the remains of land animals, such as the jackal, rat, bird, lizard, or snake, which have been seen frequenting dust-dune areas. In fact, the dust dunes of northern Egypt, known as Kardud to the inhabitants, are local deposits of Loess.

A depression of the land of only a few feet, and such as that which has taken place since Roman times in Egypt, would cause another fluviatile layer containing the common shell *Cyrena fluminalis* or a lacustrine bed to be superimposed upon them. It is thus manifest that a desertic deposit interstratified between two freshwater beds is not necessarily a proof of change of climate.

3. *Discussion on the Physiography of Arid Lands.*

Introduction. By Professor Sir T. H. Holland, *K.C.I.E., D.Sc., F.R.S.*

The principal defect in published accounts of the physiography of arid lands is due to the absence of data showing the amount as well as the kind of physical changes in progress. This deficiency is to be expected. Few qualified observers are able to study arid lands for long continuous periods; such regions are thinly populated, and, from an economic point of view, their problems are of relatively small importance. It is not surprising, therefore, that, while we have abundant illustrations—pictorial and literary—regarding the nature of geological phenomena in the desert, we are only to a limited extent able to substantiate by trustworthy figures our general conclusions regarding the rates of destruction, transportation, and reproduction of desert formations.

The investigation made during the years 1903-08 of the salt resources of the Rajputana desert was undertaken on behalf of the Government of India with a definite economic object in view, and the opportunity was turned to account to make a quantitative test of one phase of desert phenomena—namely, the æolian transportation of salt in the form of fine dust.[2]

There are several intermittent saline lakes lying in depressions on the sand-covered highlands of Rajputana. In one case—namely, the Sambhar Lake—the underlying silt, tested to a depth of twelve feet over an area of 68 square miles, was found to contain some fifty-five million tons of sodium chloride. The quantities of salt so stored are altogether in excess of the amount that could be accumulated by normal fresh-water rivers acting within any reasonable geological period under present physiographic conditions. There are no rock-salt deposits known within the region under consideration, and the underlying rocks are Archæan gneisses and schists covered with a thin mantle of sand.

[1] By permission of the Director-General of the Egyptian Survey Department.

[2] For details see T. H. Holland: successive Annual Reports of the Geological Survey of India published in *Records G.S.I.* during 1904-09.

The discovery of small undamaged foraminifera in the desert sands of Barmer and Bikaner by Mr. T. H. D. La Touche [1] gave the first clue to the origin of this salt, for such foraminifera must have reached the heart of the desert by wind transportation over a distance of some five hundred miles from the coast of Cutch. Consideration of the meteorological conditions of the area increased the plausibility of this suggestion; for during the hot dry season, from April to June, strong winds blow from the south west, sometimes with the force of gales, especially during the day-time, when, under a scorching sun, the salt is absolutely dry and easily powdered. The Rann of Cutch during the hot dry season partly dries up and becomes covered with a thin incrustation of salt, so that every traveller—man or beast—crushes the hopper-shaped skeleton crystals of sodium chloride, forming puffs of fine saline dust, which are wafted away by the strong winds to the north-east and towards the desert region of Rajputana. During the hot dry season these winds maintain a constant direction; they are strong during the day, moderating to a comparative calm at nights, but there is never a set-back, and they are followed every year by the rainy season, which commences about the middle of June.

These winds are specially strong near the coast, but they diminish in force in the central part of the desert region, and there their load of saline dust becomes deposited over the surface of the sand, being washed in solution into convenient hollows during the rainy season, thus forming small lakes, which become rapidly reduced to bodies of concentrated brine during the next following dry cold weather.

During the cold weather which follows the rainy season the atmosphere is dry, and winds blow generally from the north and north-east. These winds are, however, comparatively feeble, and in any case are unable to carry an appreciable quantity of salt back to the south-west, as the salt is by then accumulated in the lakes, which are seldom completely dry before the commencement of the next following hot weather, when the recurring south-west winds bring in another load of salt-dust.

By the elimination of all other possible sources of the salt in the lakes of the Rajputana highlands, and by consideration of the meteorological conditions, a satisfactory theory thus became established to account qualitatively for the origin of the salt. It then became necessary to check the theory by a quantitative test, and this onerous task was undertaken by Dr. W. A. K. Christie, with the assistance of M. Vinayak Rao, of the Geological Survey of India, during the hot weather of 1908. After some months of preliminary experiments with artificial winds to ascertain the best method of collecting samples and of determining the limits of experimental error, a laboratory was built in the desert, where anemometer records, temperatures, and barometic pressures were taken at regular and frequent intervals, while samples of the wind were collected at different elevations and analysed. As a result of this work, it was found that during four months of the hot dry season of 1908 the amount of wind-borne salt passing a front 300 kilomètres broad and 100 mètres high must have been something of the order of 130,000 tons. As the meteorological records showed that the hot weather of 1908 was a season of unusually weak winds, the figure obtained is probably well below the annual average influx of salt-dust.

Although the results can thus be stated in figures, they refer to one year only, and are, in a sense, still only of qualitative value. There is no doubt, however, that they establish beyond reasonable doubt the theory which had been formulated on wider considerations, both negative and positive, as to the origin of the enormous quantities of salt now accumulated in the Rajputana desert.

It is necessary, naturally, to exercise caution in extending this theory to other desert regions, some of which are, nevertheless, areas of wind inflow during hot dry seasons. It is also significant that rock-salt deposits are frequently associated with formations that can best be accounted for as due to desert conditions, although such phenomena would be characteristic also of

[1] *Mem. Geol. Surv. Ind.*, vol. xxxv., p. 42, 1902.

areas where, as in the case of the Kara Boghaz of the Caspian, arms of the sea are partly cut off and subjected to desiccation.

Although it is dangerous to generalise from this single instance of Rajputana, in spite of its striking and conclusive character, the observations made in that region are quoted as an instance of an attempt to check by definite quantitative tests general mental impressions of geological dynamics in desert regions. The object of this communication is mainly to urge the further institution, where practicable, of such tests of current theories regarding the physiographic phenomena of arid lands.

Professor W. M. DAVIS: My interest in the subject proposed for our discussion comes from an endeavour to systematise the study of land forms, so that a well-trained explorer shall be aided in making accurate and complete observations of the ground, and in preparing afterwards for readers as expert as himself a complete and intelligible record of his observations. It would be comparatively easy to reduce such a description to simpler or shorter form for more elementary or more popular use; but it would be impossible to expand a short elementary account intended for beginners, or a popular account intended for general readers, into a detailed monograph intended for experts. The advancement of geographical science will therefore be best promoted by striving to develop a mature thoroughgoing method for the observation and description of all kinds of land forms, including those of deserts.

Much assistance has been given to the study of land forms in general by working out their evolution as dependent (1) on their structure, (2) on the erosional process that works upon them, and (3) on the stages which the forms produced by the work of process on structure pass through, from the initial stage introduced by the movement of a land mass into a new attitude, to the ultimate stage when the process concerned has done all its work.

If we classify what has already been accomplished in this direction with respect to the erosional processes involved, it appears that the theoretical sequence of changes determined by the action of ordinary or normal processes on various structures has been worked out with encouraging success, and verified by confrontation with many examples of actual forms. The explanatory method of describing land forms, based on this theoretical sequence, is now employed by a number of geographers. The same is true of marine erosional processes and of solutional processes. It is less true of glacial processes, though much good progress has been made in that division of the general subject.

With regard to arid processes, theory has outstripped observation; hence the observational study of deserts is much to be desired as a means of testing, correcting, and extending the theory of arid erosion. The difficulty with the descriptions of desert forms hitherto published is that they are so largely empirical and so incomplete that it is impossible to translate them into the phrases of rational or explanatory physiography. Hence what we now need is, *the exploration of deserts by trained students, well informed regarding modern physiographic theories.*

Let me illustrate this by a special case. The theory of the evolution of desert forms includes a stage in which a lower basin is about to capture the centripetal wash of a neighbouring higher basin; and another stage in which such a capture has recently taken place. The significant characteristics of each of these two stages, as well as of many earlier and later stages, have been defined with sufficient detail to make their recognition easy, provided that the observer is familiar with them; but it would be as unlikely that an observer untrained in physiography would see and describe the essential features of these stages of desert forms as that an observer untrained in botany would see and describe the essential features of plant forms. If one looks through various accounts of desert exploration, it is usually impossible to determine whether actual examples of imminent or of recent basin captures—or of any other special features of desert evolution—actually occur.

The most helpful suggestion that I can offer in this connection is that the effort should be made to refer every element of desert topography first to its proper place with respect to the surrounding contemporary elements in the general working of the processes of desert erosion, and, second, to its proper

place in the long succession of earlier and later forms between which it stands; for when the elements of a desert landscape are thus seen to be related to many other elements, all systematically disposed in time and place, their observation and their description are greatly facilitated.

The equipment of an explorer of deserts with a good knowledge of the theory of desert evolution is therefore, as I see it, about as important as his equipment with good horses or camels, if it be desired that he should come back from his work with a critical record of what he has seen.

Professor J. W. Gregory remarked that though Scott and R. L. Stevenson used the term desert in its old sense for any uninhabited land, at present the word is restricted to lands uninhabited owing to their arid climate. No numerical limit of desert can be given; and, as Walther has stated, desert cannot be absolutely defined on biological, morphological, or climatic grounds. The cause of desert is not only climatic; geological and geographical structure are both also influential; countries of permeable or friable rocks, and existing as a plateau with an easy drainage to the adjacent lowlands, are easily rendered desert. The climatic influence depends more on the complex conditions which govern the utilisation of the rain and not on its total amount. Proximity to the sea is consistent with the development of desert conditions.

Desert is often more easily utilised than at first appears possible; since the soils often contain such rich accumulations of plant foods that the land is very fertile when watered. Australian soils often need the addition of phosphate, since they contain less phosphorus than the amount held by some authorities to be necessary for profitable cultivation.

He thought that the only explanation of the low phosphorus content in Australian soils and the absence of the usual enrichment of phosphorus in the soil as compared with the subsoil is that proposed by Professor Cherry, who attributes these facts to the rarity of mammals in Australia. In some cases in Australia the poverty of phosphate has been more influential than the aridity in developing desert conditions.

Professor A. Penck: Deserts are regions of the globe which are not only dry but are characterised also by the want of vegetation. Taking such a definition, Australia has only very few deserts; most of what is called Australian desert, indeed, has scrub, even timber. The surface forms of the deserts are more closely controlled by water than by wind. The latter heaps up the dunes, but its erosive action is rather insignificant in comparison with waterwork exercised after rare local rain-showers. Besides this, the surface of many parts of our deserts has been shaped by water before the desert conditions came in. But there are deserts which have been deserts for a very long period. There has been since the end of the Tertiary period a repeated shifting of the climatic belts of the earth, which can be observed especially at the equatorial and polar border of the desert belts, but from the central parts the belt was not shifted away.

Mr. Griffith Taylor: The arid region which I know best is situated in 78° South latitude, but I propose also to discuss the central arid region in Australia.

In Antarctica are many features which closely resemble those described from the desert. Angular breccias are being formed abundantly along the facets of all the glacier valleys in 78° S. Dreikanter are numerous. Striæ are almost absent over miles and miles of moraine. The difficulty of determining the origin of such deposits in fossil condition is obvious.

Professor Gregory has always taken an optimistic view of our own arid region, perhaps I am less sanguine. It behoves us thoroughly to realise the greatness of the problem seeing that approximately one million square miles has less than 10 inches of rainfall. Our visitors who have just seen the region in Western Australia have only penetrated the southern fringe. Moreover, 10 inches of rain in the south mean infinitely more than in the north where evaporation is so great.

I hope to see a physiographic survey along the 10-inch isohyet initiated, to

determine if there be a distinct difference such as Goyder demonstrated in so masterly a manner as a safe wheat line (near 13 inches) in South Australia. Only by such necessary research can we really gain adequate knowledge of the potentialities of Australia.

Mr. E. J. Andrews: The observations of the writer in lands of sub-arid, or arid, character have been made only in Eastern Australia and in Arizona, Nevada, and California in the United States. In these regions the surface forms testify to the dominating influence of stream action and to the utterly subordinate action of the wind in sculpturing the lands. To appreciate the part taken in the actual sculpture of desert lands by wind action alone, it is necessary to recognise the fact that ordinary water streams produce peculiar forms, and that these forms are not the result of the stream activity during normal periods, but only during periods of great floods acting perhaps once in a decade. Such forms, however, are continuously mistaken for those due to wind action, by various observers, and from interpretations such as these the action of the wind as an eroding agent is magnified unduly.

The thalwegs of the Australian and American valleys commence in well-marked divides, and their slopes thence decrease continuously towards base-level. Tributary thalwegs also enter the main valleys at accordant slopes. The bases of these valleys are occupied by pebbles and boulders, while these again are covered with deposits of clay and sand. Moreover, certain plants characteristic of fairly humid conditions elsewhere occur sporadically in oases in Eastern Australia within sub-arid regions, and this evidence taken as a whole indicates a very recent decrease in the amount of precipitation in drier Eastern Australia. Such action has only slightly modified the general appearance of the land forms developed in a previous cycle, save for killing off much of the vegetation of that previous cycle.

Mr. A. L. Du Toit referred to the dry region of German South-West Africa and the Kalahari. In the coastal sandy wastes, though wind etching is conspicuous, no hollows due to the action of the wind are to be found. Inland, hollows called 'pans,' often saline and usually periodically filled, occur sunk below the general surface, and must have been produced by wind erosion. All kinds of pans, from 'living' to 'fossil,' can be found, just as in the case of the sand dunes.

Mr. A. T. Kenyon: The general trend of the speakers' remarks showed that desert or rather arid occurrences were distinctly local, and no generalisation could now be made. The area in Victoria which might be called arid was only so on account of its rainfall, which averaged about 14 inches. Its vegetation was abundant. No definition of desert had yet been made which was really applicable to it.

The reference to Goyder's rainfall line, which was undoubtedly fixed by the occurrences of salsolaceous vegetation, needed some comment. Salt bushes grow on soils suitable to their demands, and rainfall was only a small factor. The southern limits of *Heterodendron oleaifolium*, which agreed with the line of distinct change from the *Buloke* or hybrid type of *Belar* to its typical form, was a more reliable guide; but profitable agriculture had long passed even that limit.

In regard to Victorian Mallee saline occurrences, these undoubtedly were confined to the lowest trough of a synclinorium, and were the exposed surfaces of underground sheets of salt water. This has been proved by a number of bores. They were also accompanied by beds or mounds of gypsum or *copi* as locally named, and lime carbonate. The artesian waters of the underlying marine beds held the same salts in similar proportions.

In general, lakes or swamps, the terminals of water-courses, were fresh, as were also the swamps or lakes corresponding with Dr. Du Toit's pans, and dependent upon local catchment only for their water supply.

In regard to sand ridges these æolian drifts occur all over Victoria in the western and north-eastern portions, which are the most fertile parts of the State. In the Mallee the size and arrangement of the ridges seem to be

particularly influenced by the character of the soil. In the better parts of the Mallee, with stiff clayey soil, they are with difficulty describable. In the more sandy and medium agricultural soils they had a marked parallelism and were of moderate size, but in the sand-hill and heath country (locally known as desert) this parallelism was of a general character only, and the sand-hills or ridges were known as 'jumble.' Some of these hills were as much as two hundred feet in height above the surrounding surface. None could be described as 'dune morte,' neither was it at all evident that they were fixed or fossil dunes, the more likely theory being that they were still being formed by action of single sand-grain movements. Owing to the weather being a succession of cyclones there was no prevailing direction of wind, though the westerly course of these depressions might be taken as generally governing the main sweep of the winds. Taking this as a general direction the ridges run with it and not at right angles.

The east winds seldom occur, but frequently are of great force; they never shift any sand. All other winds, particularly the north-west, west, and south-west winds, shift sand, but only in places where man has removed the natural protection of herbage either by clearing or cultivation or by fires occurring in times of drought. None of the sand shifted is air-borne, but is rolled along the surface of the ground. At Wirrengren Plain, the termination of the outlet creek or the final flow of the Wimmera River, there were in the drought of 1902 after a bush-fire had swept over the sand-hills on the west some 500,000,000 cubic yards of sand, or at the rate of 50,000,000 per mile in length drifted on to the plains. In the succeeding year, one of good rainfall, the herbage again fixed the sand-hills, while the sand on the plain gradually drifted eastwards until four years ago the plain was again in its original condition. Similarly the outlet creek itself in its course of fifty miles through white sand hills retained its original section; the sand blown in at certain exceptional seasons gradually drifting out to the east.

Supplementing Professor Gregory's remarks on the phosphoric acid contents of Victorian soil, it should be pointed out that the Mallee soil contained only about twenty parts per 100,000 or one-half of the average Victorian soil. This refers to the agricultural part of the Mallee, whereas in the sand-hill and heath country the amount of phosphoric acid was hardly ascertainable by chemical methods, and it was practically non-existent.

The methods of farming which led to the successful occupation of all this country originated in South Australia over forty years ago, where the recently christened 'dry farming' had resulted in the prosperous and productive settlement of land with under 10 inches annual rainfall. The cost of production of wheat was under 1*s*. 6*d*. per bushel, and there were at least a hundred million acres suitable for its cultivation.

Dr. W. F. Hume: The characters of an arid land cannot be separated from its past history, and in Egypt five physiographic features of first importance have to be considered. These are:—

1. A belt of deep depressions in the extreme west, the famous Oases.
2. The broad waterless expanse of the Western or Libyan Desert, to the west of the Nile, and the corresponding limestone plateau region (the Maaza Limestone Plateau) to the east of the river.
3. The Nile Valley with its Delta.
4. The Wilderness of the Red Sea Hills and Sinai with its rugged mountains and tortuous valleys.
5. The Red Sea and its narrow prolongations, the Gulfs of Suez and Akaba, together with the coastal plains.

Each of these divisions requires separate treatment. The paper gives a rapid sketch of the geological history of Egypt as known to us at present, the formation of the ancient core of Pre-Cambrian or Palæozoic sediments, volcanic rocks with invasion by granitic magmas, the brief Carboniferous marine advance, and later the much more important Jurassic-Cretaceous transgression, which practically affected almost the whole of Egypt, giving rise to the Nubian Sandstone and the important phosphate-bearing Cretaceous series. The Eocene strata which form the major portion of Central Egypt are probably formed, at the base, of

re-made Cretaceous material, and only in their upper portions show marked evidence that the underlying sandstones and igneous rocks are undergoing erosion.

The re-arranging of Cretaceous strata eroded during Eocene times is regarded by the writer as explaining the great difficulty experienced in drawing a lithological line of unconformity between the beds of these respective periods, though the faunal differences indicate the great break between them.

Fringing the pre-Eocene and Eocene areas of Egypt are a series of Miocene and more recent formations which are of great interest both from tectonic and economic points of view.

In considering the separate physiographic features it is pointed out :—

(A) In the formation of the Oases it is necessary to consider the denudation of the area by marine erosion while rising from the sea and the effects of former more humid climatic conditions. Where the Nubian Sandstone or other soft beds have been exposed, as Beadnell has pointed out, the Oases depression without outlet is produced by wearing through wind-blown sand.

(B) The Great Plains of the Libyan Desert are regions of low dip, of meagre rainfall, and thus wind is the dominant factor. A sandy region to the north supplies the sand necessary for erosion. The character of the desert surface depends on the nature of the geological strata present. The undulating gravel plateaux, or *serir*, the limestone expanse, the 'melon' country, and the fossil floors are various forms in which the desert presents itself, the main feature being the removal of all particles capable of being transported by wind. These are deposited as sand-falls in the wind-shadows of the Nile Valley scarp or other depressions. The sand-dunes which are locally developed are in sharp contrast to the main desert, these probably depending on three main factors, the existence of sandy deposits, determining their source of origin, the usual direction of the wind their trend, and the relief of the ground their position.

The Maaza Limestone Region is similar to the Libyan Desert, but has a greater rainfall. It thus presents a fine example of the effects when rain acts during short periods on rock-surfaces affected by temperature variations. Deep ravines, remarkable water-holes, caverns, natural bridges, and surface coloration films due to the trickling down of ferruginous solutions over cliff-walls are among the prevailing features in the southern part of this area.

(C) The present course of the Nile Valley appears to depend on three factors : (*a*) The formation of the syncline, the axis of which it partly follows; (*b*) the erosion of the softer strata along their outcrops determining the present north-south trend of the major courses of the river; and (*c*) the possible effect of the rotation of the earth (Van Baer's law), the stream tending to hug its eastern bank. Attention is called to the region of exceptional erosion where heavy masses of Eocene limestone rest on and have slipped over the subjacent soft Cretaceous marls and slates. These slips must have been connected with greater rainfall and earth-movement as widespread terraces extend in front of the main cliff and rise to some 110 mètres above the present river-level. The triple terracing of the Nile is briefly considered.

(D) The Mountain Region of the Eastern Desert is essentially an anticlinal area, where tension is in excess of compression. The differential movements are considerable, minor folds play a conspicuous part, and great fractures determine earth-features of considerable magnitude. The result is that the masses of granite and metamorphic rocks hidden beneath the surface in Central Egypt are here exposed by denudation, forming the Red Sea Hills and Sinai mountains.

The different geological formations give rise to very varied surface features. Attention is called to the importance of rain as a sculpturing agent. The soft Nubian sandstone is easily eroded both by wind-borne sand and by water, giving rise to conspicuous depressions. In the granitic areas temperature variation breaks up the solid rock, huge domes are produced by flaking off of concentric shells. Dykes give rise to marked differences in surface outline, the harder quartz-porphyries determining the form and general trend of many of the mountain summits, while the softer diabases, being easily eroded, give rise to gullies seaming the precipitous sides of the granitic hills. The general character of the country where schists and volcanic rocks are present is also described.

(E) In the Gulf of Suez area another factor has come into play. Here sea-arms project far inland between land-surfaces subject to desert conditions, and their waters become centres of far-reaching chemical activity. Thus coral-reefs are changed to dolomites, sea-shells of carbonate of lime to gypsum, hydrocarbons are in quantities of economic importance, and mineralised areas of lead and zinc ores, of manganese oxide, of iron pyrites, and of sulphur are present in the young Tertiary beds which fill these Red Sea depressions. From Suez to beyond Halaib, that is, throughout the length of Egypt, gypsum forms a conspicuous fringe between the ancient hills and the sea, generally dipping gently seaward on the borders of the Red Sea itself. Further north, in the Gulf of Suez area, the conditions are more complicated. Dyapir, or piercing folds such as have been described by Professor Mrazec in Rumania, are of common occurrence, and there is remarkable interplay between the hard and soft members of the folded series.

The surface structure of an arid land is not only the direct reflex of its geological structure, but also of former climatic change. Many factors in Egypt point to great rainfall in the past, such as gravels of igneous material in the Nile Valley far from their source of origin, masses of travertine in the Oases, the varying terraces of the Nile Valley itself, the evidence of expansive lakes at Kom Ombo, &c.

Though the main features of a desert land depend on the geological structure and in part on past climatic conditions, there are characteristics which are typical of all arid regions. These are far removed from the great marine areas and from the zone of rainfall dependent upon solar activity in lands beneath the tropics.

These typical desert features have already been referred to, and include :—

1. The sweeping of all fine material from the surfaces of the plains by the action of the wind, and formation of plateau summits.
2. Intense scouring of these surfaces by wind-driven sand.
3. The breaking up of the most solid rocks by temperature-variation.
4. The formation of sand-dunes behind obstructions or where the relief of the ground favours their development.
5. The formation of mushroom-shaped pillars, or standing-out of harder materials on bases undercut by the sand.
6. The formation of sand-worn pebbles of typical angular outlines, the well-known Dreikante.
7. Vermicular markings on limestones, due it may be to etching during the movement of evaporating saline solutions.
8. Formation of desert-crusts by leaching out of the soluble materials contained in the rocks, with evaporation at the surface, resulting in deposition of the oxides of iron and manganese. Mr. Lucas, Director of the Survey Department Laboratory, has made a special study of these desert and river films, the latter probably only differing from desert ones in degree.
9. Flaking off of surfaces in the surface zone affected by temperature variation. Also fracture due to the same cause. Fragments of porphyry, limestone, &c., are often split into a series of parallel flakes standing vertically, their original connection to one another being clearly indicated by their close juxtaposition.

In the half-desert where rain, though brief, is intensely active while it lasts, a series of interesting phenomena are presented : deep cañon-like valleys, boulder-strewn gullies, saw-back ridges, parallel-dyke country, saline marshes, dry waterfalls or steep precipices in the valley-floors, and great talus-slopes.

Mr. Ferrar, in reply to a question asked by Professor A. P. Coleman, explained that the slope of the wadis from the watershed towards the Nile was about 1 to 1,000 and towards the Red Sea 1 to 200 or 1 to 300, but that the slope was of little moment, owing to the sudden rush of storm-water from its gathering-ground on the bare mountain-sides. He had not actually observed scratchings on rocks because they had not been sought, but he had seen great heaps of boulders in unstable equilibrium, which, if overbalanced, could not avoid being mutually scratched. He was aware that the scratches on some of

the blocks of the so-called Permian breccias were merely eroded veins or filaments of mineral which could be seen inside the rocks if they were broken across, and that there was little similarity between the wadi-breccias of Egypt and the moraine-breccias of Antarctica. With regard to Mr. Du Toit's remarks on salt-pans he agreed that dunes to leeward pointed to erosion and that therefore we should expect to find a great accumulation of dunes to leeward of the Egyptian Oases: such accumulations are wanting. Professor Penck's observations on the poleward movements of deserts could be interpreted in two ways: either the in-draught of air towards the equator carried sand from temperate zones on to the sub-desert areas, thus rendering them essentially deserts and causing a poleward migration of their edges; or, and this has an important bearing on the size of Polar ice-caps, our earthly boiler and condensers (the Tropics and the Poles) are losing in efficiency, and consequently both regions are becoming drier. The Wastwater Screes were a known example of breccias forming in a region whose climate is hardly desertic.

Mr. Ferrar said he was well aware that the Nubian Sandstone was exposed in the floors of the oases and that vast quantities of rock-material had been removed, nevertheless he still found himself in Professor Walther's position of ten years ago, and, after seeing wind-driven sand tending to fill the oases-depressions and not excavate them, did not think the wind-erosion theory consistent nor a sufficient explanation of their origin. He holds the view that wind-erosion tends to remove all rugosities and that the ultimate physiography of an arid land-surface is a smooth level plain.

With regard to Sir Thomas Holland's criticism as to quantitative results, Mr. Ferrar suggested that data, similar to that collected in Rajputana by the Indian Geological Survey, could be obtained by measuring the quantity of sand brought in to the oases at their northern ends and the quantity carried out southwards. Any difference would show the rate of erosion or deposition, according to sign.

In concluding his remarks Mr. Ferrar thanked his audience for their interest in and their appreciation shown towards his papers.

After remarks by Mr. D. M. S. Watson, the discussion closed.

WEDNESDAY, AUGUST 19.

The following Papers were read :—

1. *On the Age and Sequence of the Tertiary Strata of South-Eastern Australia. By* Frederick Chapman, *A.L.S.*

Divisions of the Kainozoic.

It is convenient to divide the Australian Tertiary system into four or five main series, using the local terms suggested by Hall and Pritchard. In ascending order, these, according to the writer, are :—

1, Balcombian. 2, Janjukian. 3, Kalimnan. 4, Werrikooian. Above these comes the Pleistocene series, referred by many geologists elsewhere to a separate system, the Quaternary.

These divisions, broadly speaking, correspond with :—

1, Oligocene. 2, Miocene. 3, Lower Pliocene. 4, Upper Pliocene.

The present writer maintains that, giving due allowance to time discrepancies in regard to the factor of distribution of life-forms over wide areas, guide fossils are probably as important in dividing and allocating these beds to the well-known horizons of the northern hemisphere as are percentages of living forms in these fossil deposits. The percentage method can only be used with safety as an approximate guide to age, seeing the difficulty of obtaining an agreement amongst zoologists as to what constitutes a species.

The above series of European divisions correlated with the Australian corresponds almost exactly with McCoy's original determinations, augmented by

observations on faunas and stratigraphic relationship of the beds made by the writer during twelve years' attention to this subject.

Sequence of the Beds.

With regard to the sequence, some Victorian authors hold the opinion that the Janjukian series is older than the Balcombian; but the confusion seems to have arisen from the occurrence of a large number of persistent species, especially of mollusca, passing up from the argillaceous Balcombian into the Janjukian clay series. Where faunistic and stratigraphic relationships were both doubtful the term Barwonian was suggested, which included both Balcombian and Janjukian. If, however, we regard the scope of the Janjukian in its broad sense as embracing all phases of sedimentation, of one long time series, the term Barwonian is no longer needed, its members being included in the term Janjukian. The sequence of the beds 1, 2, and 3 as given here has lately been established by the author from evidence obtained in cliff-sections at Muddy Creek near Hamilton, and in the bores put down in the Mallee and at Sorrento.

Other authors since McCoy agreed as to the present sequence, but differed in regard to the age of the oldest beds, which they held to belong to the Eocene, making the succeeding beds correspondingly older.

Guide Fossils.

The various members of the Australian Kainozoic system have been referred by the writer to the horizons given above, chiefly through a study of the cetacean types, the fish remains, the mollusca, the polyzoa, the ostracoda, and the foraminifera. In the oldest beds (Balcombian) a predominant fossil is *Amphistegina*, long mistaken for *Nummulites variolaria*, the latter genus in reality being absent. In the limestone phase of the succeeding Janjukian beds the Miocene type of toothed whale, *Parasqualodon*, occasionally occurs; in the marls the Miocene genus *Spirulirostra*; whilst the Burdigalian forms of *Lepidocyclina* are abundant in the polyzoal series of the Janjukian. In the Kalimnan series cetacea known elsewhere in the Pliocene Crag (Diestian and Astian) of Antwerp and England, as *Scaldicetus* and the ziphioid whales, are characteristic fossils. The above interpretation of the Australian Tertiary sediments agrees also with the data acquired by Australian physiographists, and is that generally accepted for New Zealand and Patagonia.

Terrestrial Series.

The terrestrial Tertiary deposits, so far as they are known, are assigned to the various horizons as follows :—

Balcombian.—Leaf-beds of Mornington and the brown coal of the Altona Bay Coal-shaft.

Janjukian.—Leaf-beds of Sentinel Rock (Cape Otway), Haddingley near Bacchus Marsh, Pitfield Plains, Narracan, Dargo High Plains and the Older Deep Leads : in Victoria. Leaf-beds of Dalton, Gunning, and Vegetable Creek : in New South Wales. Leaf-beds of Lake Frome, &c. : in South Australia.

Kalimnan.—Newer Deep Leads, Haddon, Victoria. Also of Gulgong in New South Wales.

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2. *The Age and Sequence of the Victorian Tertiaries.* *By* T. S. HALL, *M.A., D.Sc.*

The chief difficulty that meets one in attempting to decide the age of the marine Tertiaries of Southern Australia is their wealth in well-preserved fossils. From the oldest series, the Barwonian, which includes the closely allied Janjukian and Balcombian, about 1,800 species have been described. This includes over 800 mollusca, some 500 polyzoa, and about 40 brachiopoda, 50 echinoids, 80 corals, and a large number of foraminifera. The Kalimnan yields about 260 described species, mainly mollusca, while the Werrikooian affords close upon 200 species of described mollusca. It may safely be said that when the fauna of the Barwonian, at any rate, is fully described the total will be doubled, for, taking the mollusca, the small forms, which are extremely

abundant, have not been touched, and a large number of new species in almost all groups are known, but remain undiagnosed.

The basis of classification is in dispute. In spite of all objections I adhere to the Lyellian percentage method as yielding the best results. Another method has been adopted by Ortmann in dealing with the Patagonian Tertiaries. It consists in comparing each species with species of known age in the northern hemisphere, deciding which is the nearest 'ally' or 'representative,' and referring the southern formations to those northern ones which yield the greatest number of 'relationships.' It passes by as of no importance all the southern forms. Harris suggests using phylogeny *pari passu* with the Lyellian method.

The objection urged against the Lyellian method is that the personal equation enters too largely into it, and we do not know what a species is. H. von Ihering has discussed Ortmann's method fully, and objects to it. To my mind the personal equation is as prominent in it as in the Lyellian, and it demands an amount of knowledge of the Tertiary faunas of the world that no one can possibly have at first hand, and enormous collections, quantities of each species, that no museum is likely to contain. As regards phylogeny, we cannot use it till we know the sequence.

Confining ourselves to the mollusca, we find Tate recognising about a dozen recent species in the Barwonian. Later authors have more or less definitely recognised about half a dozen more. As we have over 800 named species in this series of beds, we may double the number of recent ones without seriously affecting the result.

Assuming that the Barwonian is Eocene, for some age has to be assumed, I have elsewhere discussed most of the genera that transgress.[1] Some pass up from Mesozoic times, others are extensions back from younger horizons in the north, or from recent seas. Besides this the absence of many modern genera must be insisted on. It is customary for those who hold that the Barwonian is younger than Eocene to label all the old genera 'survivals.' This hardly settles the question. Leaving the land fauna on one side, there are some undoubted survivals in the Indo-Pacific, but it may be asked, Did nothing originate in the southern seas and slowly migrate northwards? The real place of origin and age of the transgressing genera cannot be settled off-hand by northern standards.

The Barwonian is divided into Balcombian and Janjukian, but their relationship has been vigorously discussed. By far the greater part of the fauna is common to the two. Passing by the discussions between Professor Ralph Tate and Mr. J. Dennant on the one side, and Dr. G. B. Pritchard and myself on the other, which ended, as such discussions frequently do, in a series of flat contradictions as to facts, we may consider Mr. F. Chapman's position.

Mr. Chapman asserts that the Batesford limestone is typical Janjukian, and appears to conclude that all the polyzoal limestones, and there are many, are also Janjukian. He argues on the same data that the Janjukian is the younger series. Tate, Dennant, Pritchard, and myself, however much we differed on other points, agreed that the age of the limestones must be decided by reference to the rich fauna of the clays. Mr. Chapman makes no reference to an intercalated clay bed in the Batesford limestone from which Dr. Pritchard and myself collected forty-five species, mainly mollusca. Of these only one is confined to the type Janjukian locality, while twelve have never been found there, but are confined to typical Balcombian beds. The rest are common to both series. The limestone, then, as we asserted, is Balcombian and not Janjukian. Moreover, we showed, by a careful examination of the area, that the limestone passed under clays which are typically Balcombian, and can be traced to Orphanage Hill, only a couple of miles away. M'Coy grouped the Orphanage Hill beds with those of Mornington, that is, with the type Balcombian section. Tate, Dennant, Pritchard, and myself agree with the grouping, and Mr. Chapman still labels the Orphanage Hill fossils Balcombian in the National Museum. If, as Mr. Chapman asserts, the Batesford limestone is Janjukian, then the Balcombian is the younger and not the older member, as he asserts. The stratigraphical facts are unimpeachable.

The Mount Gambier limestones must, as the contained mollusca show, be

[1] *Rep. Aust. Assoc. Adv. Science*, Hobart, 1902; Pres. Addr. Sec. C.

associated with the Balcombian of Muddy Creek. The polyzoal limestone of Muddy Creek rests on quartz porphyry, and is the basal member of the series. It has been traced by Dr. Pritchard and myself passing under the more loosely compacted beds of the district, and is inseparable from them.

The polyzoal limestones of Jan Juc, Waurn Ponds, and a few other places are Janjukian, and the evidence rests on the mollusca, but this has no bearing on Mr. Chapman's main contention.

The relative age of the Janjukian and Balcombian is a difficult question. M'Coy, Tate and Dennant, and Chapman consider the Janjukian the younger. Dr. Pritchard and myself consider the reverse to be the case.

As regards the other formations, it may be briefly said that the estimate of their age depends on that of the Barwonian. If this be Eocene, they are Miocene and Pliocene respectively; if not, they must be placed higher in the scale.

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3. *On the Age and Sequence of the Victorian Tertiaries.* *By* G. B. Pritchard, *D.Sc.*

Tertiary geology in South-Eastern Australia has been fruitful of much difference of opinion, partly on account of lithological variations associated with palæontological variations which have not always received due weight, the difficulty of correlating disconnected outcrops, bores, and shafts, and the degree of antiquity and relative age of the various horizons represented. The various changes in this work have no doubt been a stimulation to some, but to many it has been, and still is, very confusing.

It happens that marine deposits are well developed, many showing a remarkable wealth of fossils, and these have attracted more attention than their terrestrial and volcanic associates. Amongst the marine fossils, mollusca are usually very striking, and it is only natural to compare these with Australian living forms. In this way a succession can be determined for the fossil faunas as at present known, showing further and further removes from the living.

(*a*) Werrikooian.—The type locality is at Limestone Creek, a small tributary of the Glenelg River, in the parish of Werrikoo, South-Western Victoria. These beds bear a molluscan fauna strictly comparable with living forms along the southern coast except for the occurrence of a few species at present unknown amongst the living fauna.

(*b*) Kalimnan.—The type locality is near the township of Kalimna, Gippsland Lakes, Eastern Victoria. The fauna of these beds is also comparable in general facies with the recent, in the proportion of bivalves to univalves, and relative abundance of representatives of other groups. It includes extinct genera, as well as a very high proportion of extinct species.

(*c*) Balcombian.—The type locality is at Balcombe's Bay, east shore of Port Phillip. The fauna of these beds is richer and more varied than the existing Southern fauna; its general facies is more comparable with Northern Australian forms. In the present state of our knowledge it contains rather more than two per cent. of extinct genera, and even allowing a wide margin for differences of opinion the living species would barely represent two per cent.

(*d*) Janjukian.—Coastal sections on Bass Strait, parish of Jan Juc, south of Geelong. The fauna from these beds appears to be furthest removed from the living, based on a review of the genera which shows between five and six per cent. extinct, whilst the species only show about one per cent. living forms.

When the typical fossils are not obtainable it is not easy to state whether a rock series is Balcombian or Janjukian. To meet this difficulty the wider term Barwonian has been given, as both these horizons are well developed in the Barwon Basin.

Stratigraphical evidence also exists in confirmation of the above sequence in the Moorabool Valley, in the coastal sections from Port Campbell to Cats' Reef and elsewhere.

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4. *On the Age of the Lower Tertiary Marine Rocks of Australia.* By R. Bullen Newton.

The author referred briefly to the valuable palæontological work on the Australian Tertiaries carried out by such prominent authors as M'Coy, Ralph Tate, Dennant, Hall, Pritchard, &c., the majority of whom favoured an Eocene Age for the Lower Tertiary deposits of Australia. The late G. F. Harris doubted the existence of such a formation, whilst M. Cossmann could see no relationships among the Lower Tertiary Opisthobranchs from Australia with Eocene forms from Europe.

Mr. F. Chapman, palæontologist of the Melbourne Museum, has studied this subject, and proves very conclusively that those beds hitherto regarded as Eocene belong to the Miocene period—a view which the author fully supports. Mr. Chapman's work on the Batesford limestone is important in this connection, because of its containing *Lepidocyclina*, *Amphistegina*, and *Lithothamnium*—all of which characterise the Miocene beds of Europe, Java, Sumatra, Borneo, Formosa, &c.; the absence of nummulites in this limestone is against its age being either Eocene or Oligocene. These same limestones have also yielded Mollusca and Brachiopoda, as well as *Carcharodon megalodon*, which has its origin in Miocene rocks. The author was of opinion that the Lower Tertiary faunas of Australia presented in some cases a recent facies, in others a Miocene facies with relationships to both European and South American species of that period. Among shells showing a resemblance to those of present-day seas, he mentioned *Cassis contusus*, *Siphonalia spatiosa*, *Typhis laciniatus*, all Tate's species, and mostly from the Muddy Creek deposits; and many more species might be quoted exhibiting a more or less recent appearance. Among fossil forms more particularly referred to was the *Aturia aturi* var. *australis*, which has been recognised as coming from the Eocene of Australia. Although given a varietal name, this Cephalopod is not to be separated from the Miocene species of Europe known as *Aturia aturi*, and with this statement Mr. Crick, of the British Museum, thoroughly agrees. The species is found in many of the Australian deposits, as also in the Table Cape beds of Tasmania, the Oamaru beds of New Zealand, the Navidad beds of Chili, South America, as also in the European Miocene. The more or less pointed rostrum of *Spirulirostra curta* illustrates an affinity with Miocene forms rather than with Eocene, which are more obtuse.

The large *Cypræas* described by M'Coy as Oligocene should more probably be regarded as Miocene, since they come from the Gellibrand River Beds, Muddy Creek deposits, &c., which also contain the *Aturia aturi*, before mentioned. The Brachiopods of the Lower Tertiary deposits of Australia show a somewhat recent facies, a striking form being *Magellania garibaldiana*—a species occurring in the Mount Gambier Beds in association with the *Aturia aturi*.

Even before Mr. Chapman pointed out the Miocene characters of the Lower Tertiary deposits of Australia, Dr. Ortmann, of the United States, had published in 1902 his important monograph on the Tertiary deposits of Patagonia, in which he compared the faunas of that continent with those of Australia. His researches were against the presence of Eocene in the Tertiaries of Australasia, and those beds hitherto recorded as such he identified as Miocene, and contemporaneous with the Pareora beds of New Zealand, Navidad series of Chili, and the Patagonian deposits, all of which showed unmistakable affinities with each other and favoured the view that a former connection existed between South America and Australasia.

The term Oligocene among Australasian marine Tertiaries, the author was inclined to abandon because of the absence of Nummulites, their place being taken by *Amphistegina* and Lepidocycline forms of Foraminifera. Such rocks he would regard as Miocene. This would apply to the Balcombian and Janjukian beds of Mornington &c. and the older deposits of Muddy Creek and other localities.

5. *The Correlation of the Australian Marine Kainozoic Deposits—Evidence of the Echinoids, Bryozoa, and some Vertebrates.* *By* Professor J. W. Gregory, *F.R.S.*

Correlations of the Kainozoic deposits which extend along southern Australia have been proposed in accordance with two main conclusions. According to the first, these deposits include marine representatives of all the Kainozoic systems from the Eocene to the Pleistocene. According to the alternative explanation, most of the deposits belong to the middle part of the Kainozoic, and include essentially one fauna. When I succeeded M'Coy in Melbourne in 1900 I had to consider this question, and carefully examined the evidence given by the two groups of animals in which I was most interested, the Echinoidea and the Bryozoa, and also compared their evidence with that of some fossil vertebrates. The second correlation seemed the better to agree with the evidence of these groups. The Echinoidea had been regarded as indicating the Eocene age of some of the deposits, for one characteristic fossil had been referred to the genus *Holaster*. This determination had, however, been revised and the fossil referred to a new genus, *Duncaniaster*, whose affinities are with much later echinoids than *Holaster*. The fossil echinoids could all be included in one fauna; some of the most characteristic species, such as *Clypeaster gippslandicus* and *Monostychia australis*, range from the Balcombian to the Kalimnan, and *Lovenia forbesi* has the same variations in the Janjukian and Kalimnan. Some of the rarer species are limited to one locality, but that is probably only due to their scarcity. The characteristic Echinoids indicate one fauna, which is essentially Miocene, though it may have overlapped with the upper Oligocene and lower Pliocene. The evidence of the Echinoids is decidedly in favour of the view that there has been one great marine transgression along the southern coast of Australia, which reached its maximum in the Miocene if it were not confined to that system.

The evidence of the Bryozoa is less definite, but when carefully examined it supports the same conclusions. Many of the genera lived in the Eocene and Cretaceous; but most weight should be given to the most specialised Cheilostomata found in these deposits. Some well-known living species, such as *Retepora beaniana*, *Smittia reticulata*, and *Porella skenei*, are found in the Victorian beds, and they indicate an upper instead of a lower Kainozoic age. The survival of some older Bryozoa is less significant than the first appearance of the highly developed upper Kainozoic species. Macgillivray in his monograph (1895) said that the Victorian Bryozoan fauna included no Eocene members, and that the different horizons represented were not very different in age. With those conclusions I fully concur.

The vertebrate evidence appears to me to support the same determination. The appearance of *Squalodon*, *Scaldicetus*, and *Ziphius*, and of such well-known species of sharks as *Carcharodon megalodon* and *Oxyrhina hastalis*, which range from the lowest to the highest of the main Victorian marine series, is in favour of those beds being not earlier than Miocene. It is true that both species have been recorded from the Eocene of the United States; but these American Atlantic deposits are not an altogether satisfactory basis for correlation; and these species make their first appearance in the standard Kainozoic succession of Europe in the Miocene, and they last on to the Pliocene.

The classification adopted recently by Mr. Chapman seems to me in essential agreement with the evidence of the Echinoids, Bryozoa, and Vertebrates, most of the marine Kainozoic beds of southern Australia belonging to the Janjukian and being of Miocene age.

6. *The Evolution of Victoria during the Kainozoic Period.* *By* D. J. Mahony, *M.Sc., F.G.S.*

The Kainozoic period in Victoria is characterised by great earth movements accompanied by volcanic action; the present topography is a consequent development.

The central highland area (Palæozoic rocks) extends from the eastern boundary of the State westwards to the Grampians; to the north and south

it is bounded by low lying plains (Kainozoic strata), which gradually broaden towards the west until they merge into one another. To the south Wilson's Promontory (granite), South Gippsland (Mesozoic), and the Cape Otway district (Mesozoic) rise above the plains. The highland area is essentially a dissected peneplain sinking from some 5,000 feet above sea level in Gippsland to 900 feet at its western extremity; the only Kainozoic rocks upon it are river gravels, lake-deposits, and volcanics.

The plains (500 feet) are areas of Kainozoic sedimentation with some interbedded and overlying volcanic rocks; the sedimentary series consists of lacustrine or estuarine beds, followed by marine clays (Oligocene), foraminiferal limestones (Miocene), and sandstones (Pliocene). These beds rest upon Palæozoic or Mesozoic rocks.

On the surface of the ancient peneplain, 5,000 feet above sea level, (?) Miocene plant-remains and river-gravels are preserved beneath basalt at Dargo High Plains. This indicates a long pre-Miocene period of quiescence followed by a great uplift. This area has not been submerged during the Kainozoic.

The nature of the Kainozoic series indicates that, outside the highland area, a gradual subsidence of considerable magnitude (Oligocene and Miocene), accompanied by volcanic outbreaks (Miocene), was followed by re-elevation to a maximum of about 900 feet above sea level (Pliocene or post-Pliocene). There is evidence to show that the movements were not uniform in direction, though the net result was depression or elevation. Bass Strait is a recently sunken area in which equilibrium has not yet been established.

The nearly horizontal position of the Kainozoic rocks indicates that the movements were vertical; and there are, moreover, examples of Kainozoic faults in which the differential movement amounts to 900 feet.

The volcanic rocks are basaltic except for sporadic occurrences of alkali rocks in Eastern, Central, and Western Victoria.

The Older Basalts are most abundant to the east of Melbourne. Some remnants occur on the ancient peneplain 3,000 feet above the present streams, but the most extensive areas are at lower levels in South Gippsland. At Flinders the Older Basalt underlies marine Miocene, and has been proved by boring to be over 1,300 feet thick, and to extend from sea level to that depth. In some instances the age can be conclusively proved, but in others the evidence is poor. These basalts are associated with the first great period of earth movements.

The Newer Basalts are most extensively developed in the western district, where their northern boundary is not far from the 500 feet contour; here they overlie marine Kainozoics. Large areas are also found on the plateau west of Kilmore and along its northern flanks. The Newer Basalts are never covered by marine deposits, except recent accumulations near the coast, their surface is little denuded, and many of the cones of loose scoria are almost perfect. It appears that the Newer Basalts mark the close of the last great movement which elevated the marine Kainozoics.

In New South Wales and South Australia earth movements on a grand scale took place during the Kainozoic period, yet volcanic action was comparatively insignificant.

7. *The Tertiary Brown Coal-beds of Victoria.* *By* H. Herman, *B.C.E., M.M.E., F.G.S.*

The brown coal-beds of Victoria are probably the thickest yet recorded in the world. The more extensive areas are the La Trobe Valley, Alberton, Altona, and Lal Lal. Minor beds are widely distributed.

The geological age has not yet been definitely fixed, except at Altona, where a brown coal-seam 140 feet thick underlies marine Oligocene beds. Flows of basalt overlie the brown coal in places, and underlie it in others. The range in age is probably from Oligocene upwards. Seams outcrop at Narracan, Thorpdale, Dean's March, Morwell, and Boolarra.

Where below the surface the seams are prospected by boring. In many bores coal of several hundred feet in thickness is shown; one bore had an aggregate thickness of 781 feet of coal in a depth of 1,010 feet. The overburden is from a few feet to 500 feet deep.

In the Alberton area of about 300 square miles and the La Trobe Valley area of 700 square miles there is probably 30,000,000,000 tons of coal. The approximate area at Altona is 200 square miles, with a probable average thickness of 50 feet of coal. At Lal Lal the coal covers three square miles with an average thickness of 80 feet.

The geological and geographical distribution of the various brown coal-seams is still being ascertained by boring; the bores are being systematically tested for calorific value, gas production, and by-products. A typical analysis of the brown coal, as freshly mined, is :—

	Per cent.
H_2O	53·00
V.H.C.	24·50
F.C.	21·50
Ash	1·00
	100·00

Sulphur	0·7 per cent.
Nitrogen	0·3 per cent.
Calorific value	5,500–6,000 B.T.U.
Evaporation value	4 lb. water
Gas per ton	6,500 cubic feet

Ammonium sulphate per ton (theoretical), 32 lb.

Experimental work has also proved that under proper conditions a firm hard briquette can be produced without the aid of an agglutinant binder. It is suitable also for use in the gas producer, the improvements in which of recent years bid fair to give brown coal an important place in the power-fuels of the world at no distant date.

SYDNEY.

FRIDAY, AUGUST 21.

After the President had delivered his Address (see p. 344) the following Papers were read :—

1. *The Geology of New South Wales.* *By* E. F. PITTMAN.

2. *The Age of the Permo-Carboniferous Glacial Beds.* *By* Dr. A. VAUGHAN.

3. *Report on the Erratic Blocks of the British Isles.* See Reports, p. 111.

4. *Report of the Committee to consider the Preparation of a List of Characteristic Fossils.*— See Reports, p. 111.

5. *Report on the Geology of Ramsey Island, Pembrokeshire.* See Reports, p. 111.

6. *Report on the Old Red Sandstone Rocks of Kiltorcan, Ireland.* See Reports, p. 113.

7. *Report on the Fauna and Flora of the Trias of the Western Midlands.* See Reports, p. 114.

8. *Report on the Excavation of Critical Sections in the Lower Palæozoic Rocks of England and Wales.*—See Reports, p. 115.

9. *Report on Geological Photographs.*

10. *Report on the Microscopical and Chemical Composition of the Charnwood Rocks.*

11. *Report on the further Exploration of the Upper Old Red Sandstone of Dura Den.*—See Reports, p 116.

12. *Report of the Committee to consider the Preparation of a List of Stratigraphical Names.*—See Reports, p. 113.

TUESDAY, AUGUST 25.

Joint Discussion with Sections D, E, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.—See p. 409.

The following Papers were then read :—

1. *On the Term Permo-Carboniferous and on the Correlation of that System. By* W. S. Dun *and* Professor T. W. Edgeworth David, C.M.G.

The term Permo-Carboniferous was originally applied to certain formations in Queensland which on stratigraphical evidence were at the time considered to belong to one and the same general system. At the time it was considered that a series of strata at Gympie, which contained an assemblage of fossils of distinct Permian affinities, were stratigraphically below another set of strata known as the Star Beds. The latter contain among other fossils *Phillipsia*, *Lepidodendron australe*, and *Aneimites*, all typical Carboniferous fossils in Australia, and the first mostly of Devonian age. Accordingly these formations were grouped together under the term Permo-Carboniferous, and the name has subsequently been widely used. It has now been proved that, so far as Queensland is concerned, the name has been given in error. The Gympie Beds are stratigraphically above the Star Beds, not below as was originally supposed. Nowhere in Australia or Tasmania has a single trilobite or *Lepidodendron* ever been found in our Carboniferous rocks proper. In the absence of a zoning of these Carboniferous rocks it is impossible to say what exactly are its equivalents in other parts of the world. If it is wholly Lower Carboniferous, as some suppose, there may be some justification for the retention of the term Permo-Carboniferous, but if its fauna and flora ascend to Upper Carboniferous, then it is suggested that there is much to be said in favour of using the term Permian instead. In Russia *Schizodus* occurs in numbers beneath the whole not only of the *Glossopteris* beds, but of the *Gangamopteris*

beds also of the Dwina system. In South America the Lower Rocks of the Santa Catharina system appear to be more Permian than anything else, and the occurrence of the strong swimming reptile Mesosaurus both in the Permo-Carboniferous rocks of South America and of South Africa suggests that the South African Permo-Carboniferous rocks also may be chiefly Permian.

In the correlation of the Australian Permo-Carboniferous formations, special emphasis is laid on the Indian facies of the West Australian Permo-Carboniferous fauna.

2. *The Great Australian Artesian Basin and the Source of its Supply. By* E. F. Pittman.

3. *The Geological Relations of the Artesian Water-bearing Beds of Southern Queensland. By* S. Dunstan.

4. *The Post-Jurassic Geography of Australia. Notes on the Hypothesis of Isostasy. By* E. C. Andrews.

The doctrine of isostasy implies the general correspondence, in weight, of all vertical columns of unit size composing the Earth's crust to a depth known as the *depth of compensation.* This depth is taken at 122 kilomètres below sea level by Hayford.[1]

The excess of height of the unit columns, in continental areas, is considered as being compensated by the excess of crustal density in suboceanic areas. Isostatic compensation is supposed to follow rapidly upon loading and unloading. Examples of such loading are sedimentation and the formation of a continental Ice Sheet, while examples of unloading are erosion and the disappearance of an Ice Sheet. The adjustment is considered to be a gradual, rather than a spasmodic, process. Anomalies of gravity, however, are recorded from many localities, and Gilbert[2] suggests that the explanation of such is to be sought in *nucleal heterogeneity.*

Geography.—East and West Australia form two positive, or buoyant, elements, while the Inland Plains, in the main, represent a negative, or sunken, area. With these three elements should be considered New Zealand, Malaysia, the South Pacific, the Indian, and Southern Oceans.

During Cretaceous time a great plain of erosion appears to have been formed in the positive elements of Australia, while the extensive epicontinental sea of that period was filled with the waste derived from the neighbouring erosion. Subsequently, both the old plain of erosion and the northern portion of the area of sedimentation were elevated to a moderate height and a long period of equilibrium and erosion ensued. This sequence of elevation and of pauses of equilibrium with erosion was repeated until the close of the Kosciusko Period,[3] the pauses between the uplifts becoming less important, but the amount of vertical movement becoming correspondingly emphasised.

At various stages of the process basalts flooded Eastern Australia, especially in areas of older sedimentation. The appearance of the old basalt-covered stream-drifts is suggestive of a temporary subsidence for the plateau areas during the basaltic period.

Strong streams, such as the Shoalhaven and the Hawkesbury, maintained their general courses against the uplifts along their lower portions. Hence it is inferred that the uplifts were effected slowly, nevertheless the periods of equilibrium separating the revivals of elevation were of much longer duration than the uplifts themselves.

[1] Hayford, J. F., 'Figure of the Earth and Isostasy,' *U.S. Coast and Geodetic Survey*, Washington, 1909.

[2] Gilbert, G. K., 'Interpretation of Anomalies of Gravity,' *U.S. Geological Survey*, Washington, 1913.

[3] Closing Tertiary.

The researches of Dutton, Hayford, Bowie, Gilbert, and others appear to have placed the doctrine of isostatic compensation upon a firm basis; nevertheless, the operation of the adjustments does not appear, as yet, to be understood, and it is probable that cognisance has not been taken of all the factors.

In the example cited, of the elevation of both the Great Mesozoic peneplain and a great portion of the loaded offshore area, it seems difficult, under the doctrine of continuous compensation, by erosion and sedimentation, to explain, in the first place, how the positive element could remain, for ages, in the one general position of equilibrium, while the offshore area was being loaded; and, in the second place, how the elevatory movement could have received its initial impetus, especially as the effect appears greater than the cause if it be assumed that the Cretaceous sedimentation gave rise to the Tertiary uplifts. On the other hand, the foundering of suboceanic areas in the neighbourhood might be adduced as an explanation, but the evidence is not at all conclusive on this point.

The history of the revivals of elevation during Tertiary time over Eastern Australia indicates crustal adjustment by jumps, and in this case also the increasing amount of vertical movement suggests that the elevations of the plateaus more than compensate for the erosion sustained in these regions during recent geological time.

The extrusion of the basalts is in harmony with the doctrine, but the action appears to have been catastrophic, rather than gradual, in nature.

The sequence of geographical forms cited suggests that sedimentation influenced the formation of plateaus only in a minor degree, but, on the other hand, that stresses accumulated gradually within the zone of compensation, until a belt of weakness, or mobility, was established by means of which the ill-adjusted portions were connected. Upon the arrival of such a stage adjustment ensued with relative rapidity with the production of epeirogenic uplifts and depressions. This neither denies the ability of a load, such as a mass of sediments, or an Ice Cap, to depress the underlying region, nor does it seek to exclude the tendency for an unloaded area to rise; it merely assigns to such agents a subordinate part in the shaping of the greater features of the Earth's crust.

It is probable also that an analysis of a series of gravity measurements which may be taken hereafter in Australasia would reveal the existence therein of gravity anomalies, and it is probable also that the disposition of these would be other than those which might have been inferred from a mere inspection of the topography.

5. *The Metallogenetic Provinces of Eastern Australia. By* C. A. Sussmilch.

6. *New Evidence for Darwin's Theory of Coral Reefs. By* Professor W. M. Davis.

7. *The Genesis of the Diamond in New South Wales. By* L. A. Cotton.

8. *The Occurrence of Spilitic Lavas in New South Wales. By* W. N. Benson.

9. *Structural Features of the Coal-fields of Pennsylvania and their Influence on the Origin of Hard Coal. By* Professor E. S. Moore, *M.A., Ph.D.*

There are two main coal-fields in Pennsylvania, the Bituminous and the Anthracite. The latter field comprises an area of approximately 480 square miles situated in the highly folded portion of the Appalachian Province, while the

former field covers a much larger area with but gently folded strata. Between these two fields are limited areas underlain by semi-anthracite coal in strata which have suffered a medium amount of diastrophism.

So close is the relationship between intense diastrophism and the development of anthracite coal, that the influence of pressure—combined with conditions favourable for the escape of the volatile constituents from the vegetable matter—seems to be self-evident, although other theories, such as the action of bacteria, &c., have been advanced to account for the origin of anthracite. The structure of some of the anthracite basins is extremely complex, and the coal can often be mined only by special methods, especially where the Mammoth seam reaches 60 feet in thickness.

In the Bituminous field, 'rolls' and 'horsebacks' are common, and investigation has shown that these are, usually, nearly parallel to the larger mountain structures.

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION: PROFESSOR ARTHUR DENDY, D.Sc., F.R.S.

MELBOURNE.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

Progressive Evolution and the Origin of Species.

THE opening years of the present century have witnessed a remarkable development of Biology as an experimental science, a development which, however full of promise it may be for the future, for the time being appears to have resulted in a widespread disturbance of ideas which have themselves only recently succeeded in gaining general acceptance. The theory of organic evolution, plainly enough enunciated at the close of the eighteenth and the beginning of the nineteenth century by Buffon, Lamarck, and Erasmus Darwin, remained unconvincing to the great majority of thinking men until the genius of Charles Darwin not only brought together and presented the evidence in such a manner that it could no longer be ignored, but elaborated a logical explanation of the way in which organic evolution might be supposed to have taken place. Thanks to his labours and those of Alfred Russel Wallace, supported by the powerful influence of such men as Huxley and Hooker, the theory was placed upon a firm foundation, in a position which can never again be assailed with any prospect of success.

This statement is, I believe, entirely justified with regard to the theory of organic evolution itself, but the case is very different when we come to investigate the position of the various subsidiary theories which have been put forward from time to time with regard to what may perhaps be termed the *modus operandi*, the means by which organic evolution has been effected. It is in this field that controversy rages more keenly than ever before. Lamarck told us that evolution was due to the accumulated results of individual effort in response to a changing environment, and also to the direct action of the environment upon the organism. Darwin and Wallace taught us that species originated by the natural selection of favourable variations, and under the influence of Weismann's doctrine of the non-inheritance of acquired characters the theory of natural selection is in danger of becoming crystallised into an inflexible dogma. In recent years De Vries has told us that species arise by sudden mutations, and not by slow successive changes, while one of the most extreme exponents of 'Mendelism,' Professor Lotsy, lately informed us that all species arise by crossing, and seriously suggested that the vertebrate type arose by the crossing of two invertebrates!

This curious and many-sided divergence of opinion amongst expert biologists is undoubtedly largely due to the introduction of experimental methods into biological science. Such methods have proved very fruitful in results which at first sight seem to be mutually contradictory, and each group of workers has built up its own theory mainly on the basis of observations in its own restricted field.

Professor Bateson has said in his recently published 'Problems of Genetics': 'When . . . we contemplate the problem of Evolution at large the hope at the present time of constructing even a mental picture of that process grows weak almost to the point of vanishing. We are left wondering that so lately men in general, whether scientific or lay, were so easily satisfied. Our satisfaction, as we now see, was chiefly founded on ignorance.' [1]

In view of this striking pronouncement on the part of one who has devoted his life with signal success to the experimental investigation of evolutionary problems, the remarks which I propose to lay before you for your consideration to-day may well appear rash and ill-advised. I cannot believe, however, that the position is really quite so black as it is painted. We must perforce admit that the divers theories with regard to the working of organic evolution cannot all be correct in all their details, but it may be that each contains its own elements of truth, and that if these elements can but be recognised and sorted out, they may perhaps be recombined in such a form as to afford at any rate a plausible working hypothesis. We must bear in mind from the outset that in dealing with such a complex problem many factors have to be taken into account, and that widely different views on the question may be merely one-sided and not necessarily mutually exclusive.

I take it there are three principal facts, or groups of facts, that have to be accounted for by any theory of organic evolution :—

(1) The fact that, on the whole, evolution has taken place in a progressive manner along definite and divergent lines.

(2) The fact that individual animals and plants are more or less precisely adapted in their organisation and in their behaviour to the conditions under which they have to live.

(3) The fact that evolution has resulted in the existence on the earth to-day of a vast number of more or less well-defined groups of animals and plants which we call species.

The first of these facts appears to me to be the most fundamental, and at the same time the one to which least attention is usually paid. The great question, after all, is, Why do organisms progress at all instead of remaining stationary from generation to generation? To answer this question it is not necessary to go back to the beginning and consider the case of the first terrestrial organisms, whatever they may have been, nor are we obliged to take as illustrations the lowest organisms known to us as existing at the present day. We may consider the problem at any stage of evolution, for at each stage progress is, or may be, still taking place. We may even begin by considering what is usually regarded as the highest stage of all, man himself; and indeed this seems the most natural thing to do, for we certainly know more about the conditions of progress in man than in any other organism. I refer, of course, at the moment, not to progress in bodily organisation, but to progress in the ordinary sense of the word, the progress, say, of a family which rises in the course of a few generations from a position of obscure poverty to one of wealth and influence. You may perhaps say that such a case has no bearing upon the problem of organic evolution in a state of nature, and that we ought to confine our attention to the evolution of bodily structure and function. If so, I must reply that you have no right to limit the meaning of the term evolution in this manner; the contrast between man and nature is purely arbitrary; man is himself a living organism, and all the improvements that he effects in his own condition are part of the progress of evolution in his particular case. At any rate I must ask you to accept this case as our first illustration of a principle that may be applied to organisms in general.

If we inquire into the cause of the progress of our human family I think there can be only one answer—it is due to the accumulation of capital, or, as I should prefer to put it, to the accumulation of potential energy, either in the form of material wealth or of education. What one generation saves is available for the next, and thus each succeeding generation gets a better start in life, and is able to rise a little higher than the preceding one.

Every biologist knows, of course, that there are many analogous cases amongst

[1] *Problems of Genetics*, p. 97.

the lower animals, and also amongst plants. The accumulation of food-yolk in the egg has undoubtedly been one of the chief factors in the progressive evolution of animals, although it has been replaced in the highest forms by a more effective method of supplying potential energy to the developing offspring. It may indeed be laid down as a general law that each generation, whether of animals or of plants, accumulates more energy than it requires for its own maintenance, and uses the surplus to give the next generation a start in life. There is every reason to believe that this has been a progressive process throughout the whole course of evolution, for the higher the degree of organisation the more perfect do we find the arrangements for securing the welfare of the offspring.

We cannot, of course, trace this process back to its commencement, because we know nothing of the nature of the earliest living things, but we may pause for a moment to inquire whether any phenomena occur amongst simple unicellular organisms that throw any light upon the subject. What we want to know is—How did the habit of accumulating surplus energy and handing it on to the next generation first arise?

Students of Professor H. S. Jennings' admirable work on the 'Behaviour of the Lower Organisms' will remember that his experiments have led him to the conclusion that certain Protozoa, such as Stentor, are able to learn by experience how to make prompt and effective responses to certain stimuli; that after they have been stimulated in the same way a number of times they make the appropriate response at once without having to go through the whole process of trial and error by which it was first attained. In other words, they are able by practice to perform a given action with less expenditure of energy. Some modification of the protoplasm must take place which renders the performance of an act the easier the oftener it has been repeated. The same is of course true in the case of the higher animals, and we express the fact most simply by saying that the animal establishes habits. From the mechanistic point of view we might say that the use of the machine renders it more perfect and better adapted for its purpose. In the present state of our knowledge I think we cannot go beyond this, but must content ourselves with recognising the power of profiting by experience as a fundamental property of living protoplasm.

It appears to me that this power of profiting by experience lies at the root of our problem, and that in it we find a chief cause of progressive evolution. Jennings speaks of the principle involved here as the 'Law of the readier resolution of physiological states after repetition,' and, similarly, I think we must recognise a 'Law of the accumulation of surplus energy' as resulting therefrom. Let us look at the case of the accumulation of food-yolk by the egg-cell a little more closely from this point of view. Every cell takes in a certain amount of potential energy in the form of food for its own use. If it leads an active life, either as an independent organism or as a constituent part of an organism, it may expend by far the greater part, possibly even the whole, of that energy upon its own requirements, but usually something is left over to be handed down to its immediate descendants. If, on the other hand, the cell exhibits very little activity and expends very little energy, while placed in an environment in which food is abundant, it will tend to accumulate surplus energy in excess of its own needs. Such is the case with the egg-cells of the multicellular animals and plants. Moreover, the oftener the process of absorbing food-material is repeated the easier does it become; in fact, the egg-cell establishes a habit of storing up reserve material or food-yolk. Inasmuch as it is a blastogenic character, there can be no objection to supposing that this habit will be inherited by future generations of egg-cells. Indeed we are obliged to assume that this will be the case, for we know that the protoplasm of each succeeding generation of egg-cells is directly continuous with that of the preceding generation. We thus get at any rate a possibility of the progressive accumulation of potential energy in the germ-cells of successive generations of multicellular organisms, and of course the same argument holds good with regard to successive generations of Protista.

It would seem that progressive evolution must follow as a necessary result of the law of the accumulation of surplus energy in all cases where there is nothing to counteract that law, for each generation gets a better start than its predecessor, and is able to carry on a little further its struggle for existence with the environment. It may be said that this argument proves too much, that if it

were correct all organisms would by this time have attained to a high degree of organisation, and that at any rate we should not expect to find such simple organisms as bacteria and amœbæ still surviving. This objection, which, of course, applies equally to other theories of organic evolution, falls to the ground when we consider that there must be many factors of which we know nothing which may prevent the establishment of progressive habits and render impossible the accumulation of surplus energy. Many of the lower organisms, like many human beings, appear to have an inherent incapacity for progress, though it may be quite impossible for us to say to what that incapacity is due.

It will be observed that in the foregoing remarks I have concentrated attention upon the storing up of reserve material by the egg-cells, and in so doing have avoided the troublesome question of the inheritance of so-called acquired characters. I do not wish it to be supposed, however, that I regard this as the only direction in which the law of the accumulation of surplus energy can manifest itself, for I believe that the accumulation of surplus energy by the body may be quite as important as a factor in progressive evolution as the corresponding process in the germ-cells themselves. The parents, in the case of the higher animals, may supply surplus energy, in the form of nutriment or otherwise, to the offspring at all stages of its development, and the more capital the young animal receives the better will be its chances in life, and the better those of its own offspring.

In all these processes, no doubt, natural selection plays an important part, but, in dealing with the accumulation of food material by the egg-cells, one of my objects has been to show that progressive evolution would take place even if there were no such thing as natural selection, that the slow successive variations in this case are not chance variations, but due to a fundamental property of living protoplasm and necessarily cumulative.

Moreover, the accumulation of surplus energy in the form of food-yolk is only one of many habits which the protoplasm of the germ-cells may acquire in a cumulative manner. It may learn by practice to respond with increased promptitude and precision to other stimuli besides that of the presence of nutrient material in its environment. It may learn to secrete a protective membrane, to respond in a particular manner to the presence of a germ-cell of the opposite sex, and to divide in a particular manner after fertilisation has taken place.

Having thus endeavoured to account for the fact that progressive evolution actually occurs by attributing it primarily to the power possessed by living protoplasm of learning by experience and thus establishing habits by which it is able to respond more quickly to environmental stimuli, we have next to inquire what it is that determines the definite lines along which progress manifests itself.

Let us select one of these lines and investigate it as fully as the time at our disposal will permit, with a view to seeing whether it is possible to formulate a reasonable hypothesis as to how evolution may have taken place. Let us take the line which we believe has led up to the evolution of air-breathing vertebrates. The only direct evidence at our disposal in such a case is, of course, the evidence of palæontology, but I am going to ask you to allow me to set this evidence, which, as you know, is of an extremely fragmentary character, aside, and base my remarks upon the ontogenetic evidence, which, although indirect, will, I think, be found sufficient for our purpose. One reason for concentrating our attention upon this aspect of the problem is that I wish to show that the recapitulation of phylogenetic history in individual development is a logical necessity if evolution has really taken place.

We may legitimately take the nucleated Protozoon cell as our starting-point, for, whatever may have been the course of evolution that led up to the cell, there can be no question that all the higher organisms actually start life in this condition.

We suppose, then, that our ancestral Protozoon acquired the habit of taking in food material in excess of its own requirements, and of dividing into two parts whenever it reached a certain maximum size. Here again we must, for the sake of simplicity, ignore the facts that even a Protozoon is by no means a simple organism, and that its division, usually at any rate, is a very complicated

process. Each of the daughter-cells presently separates from its sister-cell and goes its own way as a complete individual, still a Protozoon. It seems not improbable that the separation may be due to the renewed stimulus of hunger, impelling each cell to wander actively in search of food. In some cases, however, the daughter-cells remain together and form a colony, and probably this habit has been rendered possible by a sufficient accumulation of surplus energy in the form of food-yolk on the part of the parent rendering it unnecessary for the daughter-cells to separate in search of food at such an early date. One of the forms of colony met with amongst existing Protozoa is the hollow sphere, as we see it, for example, in Sphærozoum and Volvox, and it is highly probable that the assumption of this form is due largely, if not entirely, to what are commonly called mechanical causes, though we are not in a position to say exactly what these causes may be. The widespread occurrence of the blastosphere or blastula stage in ontogeny is a sufficiently clear indication that the hollow, spherical Protozoon colony formed a stage in the evolution of the higher animals.

By the time our ancestral organism has reached this stage, and possibly even before, a new complication has arisen. The cells of which the colony is composed no longer remain all alike, but become differentiated, primarily into two groups, which we distinguish as somatic cells and germ-cells respectively.

From this point onwards evolution ceases to be a really continuous process, but is broken up into a series of ontogenies, at the close of each of which the organism has to go back and make a fresh start in the unicellular condition, for the somatic cells sooner or later become exhausted in their conflict with the environment and perish, leaving the germ-cells behind to take up the running. That the germ-cells do not share the fate of the somatic cells must be attributed to the fact that they take no part in the struggle for existence to which the body is exposed. They simply multiply and absorb nutriment under the protection of the body, and therefore retain their potential energy unimpaired. They are in actual fact, as is so often said, equivalent to so many Protozoa, and, like the Protozoa, are endowed with a potential immortality.

We know that, if placed under suitable conditions, or, in other words, if exposed to the proper environmental stimuli, these germ-cells will give rise to new organisms, like that in the body of which they were formerly enclosed. One of the necessary conditions is, with rare exceptions, the union of the germ-cells in pairs to form zygotes or fertilised ova; but I propose, in the first instance, for the sake of simplicity, to leave out of account the existence of the sexual process and the results that follow therefrom, postponing the consideration of these to a later stage of our inquiry. I wish, moreover, to make it quite clear that organic evolution must have taken place if no such event as amphimixis had ever occurred.

What, then, may the germ-cells be expected to do? How are they going to begin their development? In endeavouring to answer this question we must remember that the behaviour of an organism at any moment depends upon two sets of factors—the nature of its own constitution on the one hand, and the nature of its environment on the other. If those factors are identical for any two individual organisms, then the behaviour of these two individuals must be the same. If the germ-cells of any generation are identical with those of the preceding generation, and if they develop under identical conditions, then the soma of the one generation must also be identical with that of the other.[2] Inasmuch as they are parts of the same continuous germ-plasm—leaving out of account the complications introduced by amphimixis—we may assume that the germ-cells of the two generations are indeed identical in nearly every respect; but there will be a slight difference, due to the fact that those of the later generation will have inherited a rather larger supply of initial energy and a slightly greater facility for responding to stimuli of various kinds, for the gradual accumulation of these properties will have gone a stage further. The environment also will be very nearly identical in the two cases, for we know from experiment that if it were not the organism could not develop at all.

[2] This is, of course, a familiar idea. Compare Driesch, *Gifford Lectures*, 1907, p. 214.

Throughout the whole course of its ontogeny the organism must repeat with approximate accuracy the stages passed through by its ancestors, because at every stage there will be an almost identical organism exposed to almost identical stimuli. We may, however, expect an acceleration of development and a slight additional progress at the end of ontogeny as the result of the operation of the law of the accumulation of surplus energy and of the slightly increased facility in responding to stimuli. The additional progress, of course, will probably be so slight that from one generation to the next we should be quite unable to detect it, and doubtless there will be frequent backslidings due to various causes.

We can thus formulate a perfectly reasonable explanation of how it is that the egg first undergoes segmentation and then gives rise to a blastula resembling a hollow protozoon colony; it does so simply because at every stage it must do what its ancestors did under like conditions. We can also see that progressive evolution must follow from the gradual accumulation of additions at the end of each ontogeny, these additions being rendered possible by the better start which each individual gets at the commencement of its career.

Let us now glance for a moment at the next stage in phylogeny, the conversion of the hollow spherical protozoon colony into the cœlenterate type of organisation, represented in ontogeny by the process of gastrulation. Here again it is probable that this process is explicable to a large extent upon mechanical principles. According to Rhumbler,[3] the migration of endoderm cells into the interior of the blastula is partly due to chemotaxis and partly to changes of surface tension, which decreases on the inner side of the vegetative cells owing to chemical changes set up in the blastocœl fluid.

We may, at this point, profitably ask the question, Is the endoderm thus formed an inherited feature of the organism? The material of which it is composed is of course derived from the egg-cell continuously by repeated cell-division, but the way in which that material is used by the organism depends upon the environment, and we know from experiment that modifications of the environment actually do produce corresponding modifications in the arrangement of the material. We know, for example, that the addition of salts of lithium to the water in which certain embryos are developing causes the endoderm to be protruded instead of invaginated, so that we get a kind of inside-out gastrula, the well-known lithium larva.

It appears, then, that an organism really inherits from its parents two things: (1) a certain amount of protoplasm loaded with potential energy, with which to begin operations, and (2) an appropriate environment. Obviously the one is useless without the other. An egg cannot develop unless it is provided with the proper environment at every stage. Therefore, when we say that an organism inherits a particular character from its parents, all we mean is that it inherits the power to produce that character under the influence of certain environmental stimuli.[4] The inheritance of the environment is of at least as much importance as the inheritance of the material of which the organism is composed. The latter indeed is only inherited to a very small extent, for the amount of material in the egg-cell may be almost infinitesimal in comparison with the amount present in the adult, nearly the whole of which is captured from the environment and assimilated during ontogeny.

From this point of view the distinction between somatogenic and blastogenic characters really disappears, for all the characters of the adult organism are acquired afresh in each generation as a result of response to environmental stimuli during development. This is clearly indicated by the fact that you cannot change the stimuli without changing the result.

Time forbids us to discuss the phylogenetic stages through which the cœlenterate passed into the cœlomate type, the cœlomate into the chordate, and the chordate into the primitive vertebrate. We must admit that as yet we know nothing of the particular causes that determined the actual course of evolution at each successive stage. What we do know, however, about the influence of the environment, both upon the developing embryo and upon the adult, is suffi-

[3] Quoted by Przibram, *Experimental Zoology*, English Trans., Part I., p. 47.

[4] Compare Dr. Archdall Reid's suggestive essay on 'Biological Terms' (*Bedrock*, January 1914).

cient to justify us in believing that every successive modification must have been due to a response on the part of the organism to some environmental change. Even if the external conditions remained practically identical throughout long periods of time, we must remember that the internal conditions would be different in each generation, because each generation starts with a slightly increased capital and carries on its development a little further under internal conditions modified accordingly.

At this point it may be asked, Is the response to environmental stimuli a purely mechanical one, and, if so, how can we account for the fact that at every stage in its evolution the organism is adapted to its environment? We shall have to return to this question later on, but it may be useful to point out once more that there is good reason to believe—especially from the experimental work of Jennings—that the response of even a unicellular organism to stimuli is to a large extent purposive; that the organism learns by experience, by a kind of process of trial and error, how to make the response most favourable to itself under any given change of conditions; in other words, that the organism selects those modes of response that are most conducive to its own well-being. Under the term response to stimuli we must of course include those responses of the living protoplasm which result in modifications of bodily structure, and hence the evolution of bodily structure will, on the whole, be of an adaptive character and will follow definite lines. There is good reason for believing, however, that many minor modifications in structure may arise and persist, incidentally as it were, that have no significance as adaptations.

One of the most remarkable and distinctive features of the lower vertebrates is the presence of gill-slits as accessory organs of respiration. These gill-slits are clearly an adaptation to aquatic life. When the ancestors of the higher vertebrates left the water and took to life on land the gills disappeared and were replaced by lungs, adapted for air-breathing. The change must, of course, have been an extremely gradual one, and we get a very clear indication of how it took place in the surviving dipnoids, which have remained in this respect in an intermediate condition between the fishes and the amphibia, possessing and using both gills and lungs.

We also know that even the most highly specialised air-breathing vertebrates, which never live in water and never require gills or gill-slits at all, nevertheless possess very distinct gill-slits during a certain period of their development. This is one of the most familiar illustrations of the law of recapitulation, and my only excuse for bringing it forward now is that I wish, before going further, to consider a difficulty—perhaps more apparent than real—that arises in connection with such cases.

It might be argued that if gill-slits arose in response to the stimuli of aquatic life, and if these stimuli are no longer operative in the case of air-breathing vertebrates, then gill-slits ought not to be developed at any stage of their existence. This argument is, I think, fully met by the following considerations.

At any given moment of ontogenetic development the condition of any organ is merely the last term of a series of morphogenetic stages, while its environment at the same moment—which of course includes its relation to all the other organs of the body—is likewise merely the last term of a series of environmental stages. We have thus two parallel series of events to take into consideration in endeavouring to account for the condition of any part of an organism—or of the organism as a whole—at any period of its existence :—

$$E_1\ E_2\ E_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad E_n \text{ environmental stages.}$$
$$M_1\ M_2\ M_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad M_n \text{ morphogenetic stages.}$$

Ontogeny is absolutely conditioned by the proper correlation of the stages of these two series at every point, and hence it is that any sudden change of environment is usually attended by disastrous consequences. Thus, after the fish-like ancestors of air-breathing vertebrates had left the water and become amphibians, they doubtless still had to go back to the water to lay their eggs, in order that the eggs might have the proper conditions for their development.

Obviously the environment can only be altered with extreme slowness, and one of the first duties of the parent is to provide for the developing offspring conditions as nearly as possible identical with those under which its own develop-

ment took place. It is, however, inevitable that, as phylogenetic evolution progresses, the conditions under which the young organism develops should change. In the first place, the mere tendency to acceleration of development, to which we have already referred, must tend to dislocate the correlation between the ontogenetic series and the environmental series. Something of this kind seems to have taken place in the life-cycle of many Hydrozoa, resulting in the suppression of the free medusoid generation and the gradual degeneration of the gonophore. But it is probably in most cases change in the environment of the adult that is responsible for such dislocation.

To return to the case of the amphibians. At the present day some amphibians, such as the newts and frogs, still lay their eggs in water, while the closely related salamanders retain them in the oviducts until they have developed into highly organised aquatic larvæ, or even into what is practically the adult condition. Kammerer has shown that the period at which the young are born can be varied by changing the environment of the parent. In the absence of water the normally aquatic larvæ of the spotted salamander may be retained in the oviduct until they have lost their gills, and they are then born in the fully-developed condition, while, conversely, the alpine salamander, whose young are normally born in the fully-developed state, without gills, may be made to deposit them prematurely in water in the larval, gill-bearing condition.

There can be no doubt that the ancestral amphibians laid their eggs in water in a completely undeveloped condition. The habit of retaining them in the body during their development must have arisen very gradually in the phylogenetic history of the salamanders, the period for which the young were retained growing gradually longer and longer. It is obvious that this change of habit involves a corresponding change in the environmental conditions under which the young develop, and in cases in which the young are not born until they have reached practically the adult condition this change directly affects practically the whole ontogeny. We may say that the series

$$E_1\ E_2\ E_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad E_n \text{ has become}$$
$$E_1'\ E_2'\ E_3' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad E_n',$$

and as the change of environment must produce its effect upon the developing organism the series

$$M_1\ M_2\ M_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad M_n \text{ will have become}$$
$$M_1'\ M_2'\ M_3' \quad . \quad . \quad . \quad . \quad . \quad . \quad M^{n'}.$$

We must remember that throughout the whole course of phylogenetic evolution this series is constantly lengthening, so that what was the adult condition at one time becomes an embryonic stage in future generations, and that the series thus represents not only the ontogeny, but also, though in a more or less imperfect manner, the phylogeny of the organism.

The character of each stage in ontogeny must depend upon (1) the morphological and physiological constitution of the preceding stage, and (2) the nature of the environment in which development is taking place. We cannot, however, distinguish sharply between those two sets of factors, for, in a certain sense, the environment gradually becomes incorporated in the organism itself as development proceeds, each part contributing to the environment of all the remainder, and the influence of this internal portion of the environment ever becoming more and more important.

The whole process of evolution depends upon changes of environment taking place so gradually that the necessary self-adjustment of the organism at every stage is possible. In the case of our amphibia the eggs could probably undergo the first stages of development, the preliminary segmentation, within the oviduct of the parent just as well as in the water, for in both cases they would be enclosed in their envelopes, and the morphological differences between the early stages in the two cases might be expected to be quite insignificant. But it must be the same at each term of the series, for each term is built upon the foundation of the preceding one, and the whole process takes place by slow and imperceptible degrees.

It is true that by the time we reach the formation of the vestigial gill-slits in the embryo of one of the higher vertebrates the environmental conditions are

very different from those under which gill-slits were developed in their aquatic ancestors. But what then? Are not the gill-slits also very different? The changed environment has had its effect. The gills themselves are never developed, and the gill-slits never become functional; moreover, they disappear completely at later stages of development, when the conditions of life become still more different and their presence would be actually detrimental to their possessor. The embryo with the vestigial gill-slits is, as a whole, perfectly well adapted to its environment, though the gill-slits themselves have ceased to be adaptive characters. They still appear because the environmental conditions, and especially the internal conditions, which have now become far more important than the external ones, are still such as to cause them to do so.

I think the chief difficulty in forming a mental picture of the manner in which evolution has taken place, and especially in accounting for the phenomenon of recapitulation in ontogeny, which is merely another aspect of the same problem, arises from attempting to take in too much at once. There is no difficulty in understanding how any particular stage is related to the corresponding stage in the previous generation, and the whole series of stages, whether looked at from the ontogenetic or from the phylogenetic point of view, can be nothing else but the sum of its successive terms.

It will be convenient, before going further, to sum up the results at which we have so far arrived from the point of view of the theory of heredity. We have as yet seen no reason to distinguish between somatogenic and blastogenic characters. All the characters of the adult animal are acquired during ontogeny as the result of the reaction of the organism to environmental stimuli, both internal and external. All that the organism actually inherits is a certain amount of protoplasm—endowed with a certain amount of energy—and a certain sequence of environmental conditions. In so far as these are identical in any two successive generations the final result must be identical also, the child must resemble the parent; in so far as they are different the child will differ from the parent, but the differences in environment cannot be very great without preventing development altogether.

So far, it is clear, there has been no need to think of the germ-cells as the bearers of material factors or determinants that are responsible for the appearance of particular characters in the adult organism; nor yet to suppose that they are, to use the phraseology of the mnemic theory of heredity, charged with the memories of past generations. They have been regarded as simple protoplasmic units, and the entire ontogeny has appeared as the necessary result of the reaction between the organism and its environment at each successive stage of development. This cannot, however, be a complete explanation of ontogeny, for if it were we should expect all eggs, when allowed to develop under the same conditions from start to finish, to give rise to the same adult form, and this we know is not the case. We know also, from observation and experiment, that the egg is in reality by no means a simple thing but an extremely complex one, and that different parts of the egg may be definitely correlated with corresponding parts of the adult body. It has been demonstrated in certain cases that the egg contains special organ-forming substances definitely located in the cytoplasm, and that if these are removed definite parts of the organism into which the egg develops will be missing. We know, also, that the nucleus of the germ-cell of either sex contains—at any rate at certain periods—a number of perfectly well-defined bodies, the chromosomes, and these also have been definitely correlated in certain cases with special features of the adult organisation.

Before we can hope to complete our mental picture of the manner in which organic evolution has taken place, if only in outline, it is evident that we must be able to account for the great complexity of structure which the germ-cells themselves have managed to acquire, and also to form some idea of the effect of this complication upon the development of both the individual and the race.

We must consider the origin of cytoplasmic and nuclear complications of the egg separately, for they appear to be due fundamentally to two totally distinct sets of factors. In the first place we have to remember that during oogenesis the egg-cell grows to a relatively large size by absorbing nutrient material from the body in which it is enclosed. It is this nutrient material that is used for

building up the deutoplasm or food-yolk. There is good reason for believing that the character of this nutrient material will change, during the course of evolution, *pari passu* with the changing character of the organism by which it is supplied. Doubtless the change is of a chemical nature, for we know from precipitin experiments that the body fluids of closely allied species, or even of the two sexes of the same species, do exhibit distinctly recognisable differences in chemical composition. It also appears highly probable, if not certain, from such experiments as those of Agar upon Simocephalus, that substances taken in with the food and which bring about conspicuous modifications of bodily structure, may at the same time be absorbed and stored up by the egg-cells so as to bring about corresponding changes in the adults into which the eggs develop.

There seems therefore to be no great difficulty in comprehending, at any rate in a general way, how the egg may become the repository of definite chemical substances, organ-forming substances if we like to call them so, possibly to be classed with the hormones and enzymes, which will influence the development in a particular manner as soon as the appropriate conditions arise.

Unfortunately, time will not allow of our following up this line of thought on the present occasion, but we may notice, before passing on, that with the accumulation of organ-forming substances in the egg we have introduced the possibility of changes in bodily structure, to whatever cause they may be due, being represented by correlated modifications in the germ-cells, and this is doubtless one of the reasons why the germ-cells of different animals are not all alike with regard to their potentialities of development.[5]

We now come to the question of how the nucleus of the germ-cell acquired its great complexity of structure. We are not concerned here with the origin of the differentiation into nucleus and cytoplasm and the respective parts played by the two in the life of the cell. The problem which we have to consider is the complication introduced by the sexual process, by the periodically recurring union of the germ-cells in pairs, or, as Weismann has termed it, amphimixis. This is well known to be essentially a nuclear phenomenon, in which the so-called chromatin substance is especially concerned, and it is a phenomenon which must have made its appearance at a very early stage of evolution, for it is exhibited in essentially the same manner alike in the higher plants and animals and in unicellular organisms.

Let us suppose, for the sake of argument, that when amphimixis first took place the chromatin of each germ-cell was homogeneous, but that it differed slightly in different germ-cells of the same species as a result of exposure to slightly different conditions during its past history. What would be likely to happen when two different samples of chromatin came together in the zygote? The result would surely depend upon the interaction of the complex colloidal multimolecules of which the chromatin is composed. Various possibilities would arise. (1) The two samples might differ in such a way as to act as poisons to one another, disturbing each other's molecular equilibrium to such an extent that neither could survive. This is possibly what happens when an ovum is fertilised by a spermatozoon of a distinct species, though there are, of course, exceptions. (2) They might be so alike as to be able to amalgamate more or less completely, so that there would simply be an increase of chromatin of possibly more or less modified constitution. (3) They might continue to exist side by side, each maintaining its own individual character.

In the third case the union of the two different samples would give rise to a mass of chromatin of twofold nature, and repetition of the process from generation to generation would, as Weismann has shown, result in ever-increasing heterogeneity, until the chromatin came to consist of a great number of different concrete particles, each of which might conceivably differ from all the others. But when two heterogeneous masses of chromatin meet in the zygote there may be all sorts of mutual attractions and repulsions between the different colloidal multimolecules, for all three of our supposed cases may arise simultaneously, and thus the results may become extremely complicated.

The chromatin of the germ-cells in all existing organisms is undoubtedly heterogeneous, and this heterogeneity may be to some extent visibly expressed

[5] Compare Cunningham's 'Hormone Theory' of Heredity (*Archiv für Entwicklungsmechanik der Organismen*, Bd. xxvi. Heft 3).

in its arrangement in more or less multiform chromosomes during mitosis. We may provisionally accept Weismann's view that these chromosomes are themselves heterogeneous, being composed of chromomeres or ids, which in their turn are composed of determinants.

All this complexity of structure may be attributed to the effects of oft-repeated amphimixis, a view which is supported in the most striking manner by the fact that the nucleus in all ordinary somatic cells (in animals and in the diploid generation of plants) has a double set of chromosomes, one derived from the male and the other from the female parent, and by the well-known phenomenon of chromatin reduction which always precedes amphimixis.

When we approach the problem of heredity from the experimental side we get very strong evidence of the existence in the germ-plasm of definite material substances associated with the inheritance of special characters. Mendelian workers generally speak of these substances as factors, but the conception of factors is evidently closely akin to that of Weismann's hypothetical determinants. The cytological evidence fits in very well with the view that the factors in question may be definite material particles, and it is quite possible that such particles may have a specific chemical constitution to which their effects upon the developing organism are due.

From our point of view the interesting thing is the possibility that arises through the sexual process of the permutation and combination of different factors derived from different lines of descent. A germ-cell may receive additions to its collection of factors or be subject to subtractions therefrom, and in either case the resulting organism may be more or less conspicuously modified.

By applying the method of experimental hybridisation a most fruitful and apparently inexhaustible field of research has been opened up in this direction, in the development of which no one has taken a more active part than the present President of the British Association. There cannot be the slightest doubt that a vast number of characters are inherited in what is called the Mendelian manner, and, as they are capable of being separately inherited and interchanged with others by hybridisation, we are justified in believing that they are separately represented in the germ-cells by special factors. Important as this result is, I believe that at the present time there exists a distinct danger of exaggerating its significance. The fact that many new and apparently permanent combinations of characters may arise through hybridisation, and that the organisms thus produced have all the attributes of what we call distinct species, does not justify us in accepting the grotesque view—as it appears to me—that all species have arisen by crossing, or even the view that the organism is entirely built up of separately transmissible 'unit characters.'

Bateson tells us that 'Baur has for example crossed species so unlike as *Antirrhinum majus* and *molle*, forms differing from each other in almost every feature of organisation.' Surely the latter part of this statement cannot be correct, for after all *Antirrhinum majus* and *molle* are both snapdragons, and exhibit all the essential characters of snapdragons.

I think it is a most significant fact that the only characters which appear to be inherited in Mendelian fashion are comparatively trivial features of the organism which must have arisen during the last stages of phylogeny. This is necessarily the case, for any two organisms sufficiently nearly related to be capable of crossing are identical as regards the vast majority of their characters. It is only those few points in which they differ that remain to be experimented on. Moreover, the characters in question appear to be all non-adaptive, having no obvious relation to the environment and no particular value in the struggle for existence. They are clearly what Weismann calls blastogenic characters, originating in the germ-plasm, and are probably identical with the mutations of de Vries. These latter are apparently chromatin-determined characters, for, as Dr. Gates has recently shown in the case of *Œnothera*, mutation may result from abnormal distribution of the chromosomes in the reduction division.[6]

We have next to inquire whether or not the Mendelian results are really in any way inconsistent with the general theory of evolution outlined in the earlier part of this address. Here we are obviously face to face with the old dispute between epigenesis and preformation. The theory of ontogeny which I first

[6] *Quarterly Journal of Microscopical Science*, vol. 59, p. 557.

put forward is clearly epigenetic in character, while the theory of unit characters, represented in the germ-cells by separate 'factors,' is hardly less clearly a theory of preformation, and of course the conception of definite organ-forming substances in the cytoplasm falls under the same category. The point which I now wish to emphasise is that the ideas of epigenesis and preformation are not inconsistent with one another, and that, as a matter of fact, ontogenetic development is of a dual nature, an epigenesis modified by what is essentially preformation.

We have already dealt briefly with the question of organ-forming substances in the cytoplasm, and it must, I think, be clear that the existence of these is in no way incompatible with a fundamental epigenesis. We shall find directly that the same is true of Mendelian 'factors' or Weismannian 'determinants.'

We have seen that it is possible to conceive of even a complex organism as inheriting nothing from its parent but a minute speck of protoplasm, endowed with potential energy, and a sequence of suitable environments, the interaction between the two bringing about a similar result in each succeeding generation, with a slow progressive evolution due to the operation of the law of accumulation of surplus energy. If any of the conditions of development are changed the result, as manifested in the organisation of the adult, must undergo a corresponding modification. Suppose that the chromatin substance of the zygote is partially modified in molecular constitution, perhaps by the direct action of the environment, as appears to happen in the case of Tower's experiments on mutation in the potato beetle, or by the introduction of a different sample of chromatin from another individual by hybridisation. What is the germ-plasm now going to do? When and how may the changes that have taken place in its constitution be expected to manifest themselves in the developing organism?

Let us consider what would be likely to happen in the first stages of ontogeny. If the germ-plasm had remained unaltered the zygote would have divided into blastomeres under the stimuli of the same conditions, both internal and external, as those under which the corresponding divisions took place in preceding generations. Is the presence of a number of new colloidal multimolecules in the germ-plasm going to prevent this? The answer to this question probably depends partly upon the proportion that the new multimolecules bear to the whole mass, and partly upon the nature of the modification that has taken place. If the existence of the new multimolecules is incompatible with the proper functional activity of the germ-plasm as a whole there is an end of the matter. The organism does not develop. If it is not incompatible we must suppose that the zygote begins its development as before, but that sooner or later the modification of the germ-plasm will manifest itself in the developing organism, in the first instance as a mutation. In cases of hybridisation we may get a mixture in varying degrees of the distinguishing characters of the two parent forms, or we may get complete dominance of one form over the other in the hybrid generation, or we may even get some new form, the result depending on the mutual reactions of the different constituents of the germ-plasm.

The organism into which any zygote develops must be a composite body deriving its blastogenic characters from different sources; but this cannot affect its fundamental structure, for the two parents must have been alike in all essential respects or they could not have interbred, and any important differences in the germ-plasm must be confined to the 'factors' for the differentiating characters. The fundamental structure still develops epigenetically on the basis of an essentially similar germ-plasm and under essentially similar conditions as in the case of each of the two parents, and there is no reason to suppose that special 'factors' have anything to do with it.

We thus see how new unit characters may be added by mutation and interchanged by hybridisation while the fundamental constitution of the organism remains the same and the epigenetic course of development is not seriously affected. All characters that arise in this way must be regarded, from the point of view of the organism, as chance characters due to chance modifications of the germ-plasm, and they appear to have comparatively little influence upon the course of evolution.

One of the most remarkable features of organic evolution is that it results in the adaptation of the organism to its environment, and for this adaptation

mutation and hybridisation utterly fail to account. Of course the argument of natural selection is called in to get over this difficulty. Those organisms which happen to exhibit favourable mutations will survive and hand on their advantages to the next generation, and so on. It has frequently been pointed out that this is not sufficient. Mutations occur in all directions, and the chances of a favourable one arising are extremely remote. Something more is wanted, and this something, it appears to me, is to be found in the direct response of the organism to environmental stimuli at all stages of development, whereby individual adaptation is secured, and this individual adaptation must arise again and again in each succeeding generation. Moreover, the adaptation must, as I pointed out before, tend to be progressive, for each successive generation builds upon a foundation of accumulated experience and has a better start than its predecessors.

Of course natural selection plays its part, as it must in all cases, even in the inorganic world, and I believe that in many cases—as for example in protective resemblance and mimicry—that part has been an extremely important one. But much more important than natural selection appears to me what Baldwin [7] has termed 'Functional Selection,' selection by the organism itself, out of a number of possible reactions, of just those that are required to meet any emergency. As Baldwin puts it, 'It is the organism which secures from all its overproduced movements those which are adaptive and beneficial.' Natural selection is here replaced by intelligent selection, for I think we must agree with Jennings [8] that we cannot make a distinction between the higher and the lower organisms in this respect, and that all purposive reactions, or adjustments, are essentially intelligent.

Surely that much-abused philosopher, Lamarck, was not far from the truth when he said, 'The production of a new organ in an animal body results from a new requirement which continues to make itself felt, and from a new movement which this requirement begets and maintains.' [9] Is not this merely another way of saying that the individual makes adaptive responses to environmental stimuli? Where so many people fall foul of Lamarck is with regard to his belief in the inheritance of acquired characters. But in speaking of acquired characters Lamarck did not refer to such modifications as mutilations; he was obviously talking of the gradual self-adjustment of the organism to its environment.

We are told, of course, that such adjustments will only be preserved so long as the environmental stimuli by which they were originally called for continue to exercise their influence. Those who raise this objection are apt to forget that this is exactly what happens in evolution, and that the *sine qua non* of development is the proper maintenance of the appropriate environment, both internal and external. Natural selection sees to it that the proper conditions are maintained within very narrow limits.

A great deal of the confusion that has arisen with regard to the question of the inheritance of acquired characters is undoubtedly due to the quite unjustifiable limitation of the idea of 'inheritance' to which we have accustomed ourselves. The inheritance of the environment is, as I have already said, just as important as the inheritance of the material foundation of the body, and whether or not a newly acquired character will be inherited must depend, usually at any rate, upon whether or not the conditions under which it arose are inherited. It is the fashion nowadays to attach very little importance to somatogenic characters in discussing the problem of evolution. The whole fundamental structure of the body must, however, according to the epigenetic view, be due to the gradual accumulation of characters that arise as the result of the reactions of the organism to its environment, and which are therefore somatogenic, at any rate in the first instance, though there is reason to believe that some of them may find expression in the germ-cells in the formation of organ-forming substances, and possibly in other ways. Blastogenic characters which actually originate in the germ-cells appear to be of quite secondary importance.

We still have to consider the question, How is it that organic evolution has

[7] *Development and Evolution* (New York, 1902), p. 87.
[8] *Behaviour of the Lower Organisms* (New York, 1906), pp. 334, 335.
[9] *Histoire naturelle des Animaux sans Vertèbres*, tom. i. 1815, p. 185.

led to the formation of those more or less well-marked groups of organisms which we call species? We have to note in the first place that there is no unanimity of opinion amongst biologists as to what a species is. Lamarck insisted that nature recognises no such things as species, and a great many people at the present day are, I think, still of the same opinion. In practice, however, every naturalist knows that there are natural groups to which the vast majority of individuals can be assigned without any serious difficulty. Charles Darwin maintained that such groups arose, under the influence of natural selection, through gradual divergent evolution and the extinction of intermediate forms. To-day we are told by de Vries that species originate as mutations which propagate themselves without alteration for a longer or shorter period, and by Lotsy that species originate by crossing of more or less distinct forms, though this latter theory leaves quite unsolved the problem of where the original forms that crossed with one another came from.

I think a little reflection will convince us that the origin of species is a different problem from that of the cause of progressive evolution. We can hardly doubt, however, that Darwin was right in attributing prime importance to divergent evolution and the disappearance of connecting links. It is obvious that this process must give rise to more or less sharply separated groups of individuals to which the term species may be applied, and that the differences between these species must be attributed ultimately to differences in the response of the organism to differing conditions of the environment. It may be urged that inasmuch as different species are often found living side by side under identical conditions the differences between them cannot have arisen in this way, but we may be quite certain that if we knew enough of their past history we should find that their ancestors had not always lived under identical conditions.

The case of flightless birds on oceanic islands is particularly instructive in this connection. The only satisfactory way of explaining the existence of such birds is by supposing that their ancestors had well developed wings, by the aid of which they made their way to the islands from some continental area. The conditions of the new environment led to the gradual disuse and consequent degeneration of the wings until they either became useless for flight or, in the case of the moas, completely disappeared. It would be absurd to maintain that any of the existing flightless birds are specifically identical with the ancestral flying forms from which they are descended, and it would, it appears to me, be equally absurd to suppose that the flightless species arose by mutation or by crossing, the same result being produced over and over again on different islands and in different groups of birds. This is clearly a case where the environment has determined the direction of evolution.

In such cases there is not the slightest ground for believing that crossing has had anything whatever to do with the origin of the different groups to which the term species is applied; indeed the study of island faunas in general indicates very clearly that the *prevention* of crossing, by isolation, has been one of the chief factors in the divergence of lines of descent and the consequent multiplication of species, and Romanes clearly showed that even within the same geographical area an identical result may be produced by mutual sterility, which is the cause, rather than the result, of specific distinction.

Species, then, may clearly arise by divergent evolution under changing conditions of the environment, and may become separated from one another by the extinction of intermediate forms. The environmental stimuli (including, of course, the body as part of its own environment) may, however, act in two different ways: (1) Upon the body itself, at any stage of its development, tending to cause adaptation by individual selection of the most appropriate response; and (2) upon the germ-plasm, causing mutations or sudden changes, sports, in fact, which appear to have no direct relation whatever to the well-being of the organism in which they appear, but to be purely accidental. Such mutations are, of course, inherited, and, inasmuch as the great majority of specific characters appear to have no adaptive significance, it seems likely that mutation has had a great deal to do with the origin of species, though it may have had very little to do with progressive evolution.

Similarly with regard to hybridisation, we know that vast numbers of distinct forms, that breed true, may be produced in this way, but they are simply due to recombinations of mutational characters in the process of amphimixis, and

have very little bearing upon the problem of evolution. If we like to call the new groups of individuals that originate thus 'species,' well and good, but it only means that we give that name, as a matter of convenience, to any group of closely related individuals which are distinguished by recognisable characters from the individuals of all other groups, and which hand on those characters to their descendants so long as the conditions remain the same. This, perhaps, is what we should do, and just as we have learnt to regard individuals as the temporary offspring of a continuous stream of germ-plasm, so we must regard species as the somewhat more permanent but nevertheless temporary offshoots of a continuous line of progressive evolution. Individuals are to species what the germ-plasm is to individuals. One species does not arise from another species, but from certain individuals in that species, and when all the individuals become so specialised as to lose their power of adaptation, then changes in the environment may result in the extinction of that line of descent.

It is hardly necessary to point out that no explanation that we are able to give regarding the causes of either phylogenetic or ontogenetic evolution can be complete and exhaustive. Science can never hope to get to the bottom of things in any department of knowledge; there is always something remaining beyond our reach. If we are asked why an organism chooses the most appropriate response to any particular stimulus, we may suggest that this is the response that relieves it from further stimulation, but we cannot say how it learns to choose that response at once in preference to all others. If we are asked to account for some particular mutation, we may say that it is due to some modification in the constitution or distribution of the chromosomes in the germ-cells, but even if we knew exactly what that modification was, and could express it in chemical terms, we could not really say why it produces its particular result and no other, any more than the chemist can say why the combination of two gases that he calls oxygen and hydrogen gives rise to a liquid that he calls water.

There is one group of ontogenetic phenomena in particular that seem to defy all attempts at mechanistic interpretation. I refer to the phenomena of restitution, the power which an organism possesses of restoring the normal condition of the body after it has been violently disturbed by some external agent. The fact that a newt is able to regenerate its limbs over and over again after they have been removed, or that an echinoderm blastula may be cut in half and each half give rise to a perfect larva, is one of the most surprising things in the domain of biological science. We cannot, at present at any rate, give any satisfactory mechanistic explanation of these facts, and to attribute them to the action of some hypothetical Entelechy, after the manner of Professor Hans Driesch, is simply an admission of our inability to do so. We can only say that in the course of its evolution each organism acquires an individuality or wholeness of its own, and that one of the fundamental properties of living organisms is to maintain that individuality. They are able to do this in a variety of ways, and can sometimes even replace a lost organ out of material quite different from that from which the organ in question is normally developed, as in the case of the regeneration of the lens of the eye from the iris in the newt. That there must be some mechanism involved in such cases is, of course, self-evident, and we know that that mechanism may sometimes go wrong and produce monstrous and unworkable results; but it is, I think, equally evident that the organism must possess some power of directing the course of events, so as generally to secure the appropriate result; and it is just this power of directing chemical and physical processes, and thus employing them in its own interests, that distinguishes a living organism from an inanimate object.

In conclusion I ought, perhaps, to apologise for the somewhat dogmatic tone of my remarks. I must ask you to believe, however, that this does not arise from any desire on my part to dogmatise, but merely from the necessity of compressing what I wished to say into a totally inadequate space. Many years of patient work are still needed before we can hope to solve, even approximately, the problem of organic evolution, but it seemed to me permissible, on the present occasion, to indulge in a general survey of the situation, and see how far it might be possible to reconcile conflicting views and bring together a number of ideas derived from many sources in one consistent theory.

The following Papers and Reports were then read :—

1. *Plankton.* *By* Professor Herdman, *F.R.S.*

2. *Exhibition of Lantern Slides of the Narwhal and Beluga.* *By* Professor H. Jungersen.

3. *Some Notes on a Collection of Australian Frogs.* *By* J. Booth, *M.C.E.*, *B.Sc.*

The work of which this paper is the outcome was undertaken in the hope of finding some method of determination and identification of Batrachian species, without resort to the slight dissection necessary to examine the sternal apparatus and the sacral vertebræ. The material made use of was the collection of frogs at the Melbourne University, together with some of the specimens from the National Museum, and a few privately collected.

In accordance with this original intention, stress was laid on external shape, and in order to render the description of shape more definite the particulars were expressed as far as possible numerically and in proportional measurements. The length of the specimen, from snout to vent, was taken as a basis, and other dimensions expressed in terms of it.

To facilitate these measurements, a scale was devised, by which the length of the specimen in millimètres, and other dimensions in proportional units, could easily be read off from the callipers. The particulars selected as most satisfactory for measurement were :—The depth of the chest; the length and breadth of the head; the length of the snout; the distances from eye to nostril, and between the nares; the diameter of the orbit; the width of the upper eyelid; the distance between the orbits; the diameter of the tympanum, and distance from tympanum to eye; the length of hind limb; and the length of the digits of the hand. These dimensions have been tabulated for a large number of specimens.

It was found that the description and measurement of external features could not replace observations of the skeletal girdles, the variations in which seem to be of paramount genetic significance; while the external configuration and aspect is more related to the mode of life of the animals, and largely corresponds with the classification into :—swimming, climbing or tree, and burrowing or cryptic frogs.

In the course of the work the relative value of the external characters came under review. Of these, amount of webbing on the toes seems to have been overrated, Professor Spencer having pointed out how very variable this character is in several species collected by him in the interior. Colour and markings are very definite in some cases, remarkably variable in others; but usually varying in such a way as to suggest a normal form from which the rest may be derived. This normal is probably to be found in strongly marked young specimens. Of particular markings, the vertebral line, in some species constant, in others, though normal, varies in distinctness to total absence, and again in others is very definitely present or absent. Another normal marking is the lateral face-streak, and nearly all face colourations may be considered as variations of this. An external feature closely connected with habit is the adpression of the thigh to the groin. In some species this gives rise to a difference of colour and texture in the concealed parts, while in others the groin is fully exposed and does not differ from the general surface.

With regard to classification, the scheme of the British Museum Catalogue, as applied to Australian frogs, becomes reduced to three families of the Arcifera, *Cystignathidæ*, *Hylidæ*, and *Bufonidæ*, and (on account of the record of three species of the genus *Austrochaperina*, Fry) the family *Ranidæ* of the Firmisterna.

A list of the Australian species, with references to descriptions and notes on the specimens examined, and tables of the proportionally measured dimensions, were appended.

4. *Species of Victorian Lampreys.* *By* J. A. LEACH, *D.Sc.*

Richardson (1848) was the first to name an Australian lamprey (*Petromyzon mordax*).

Gray, in the British Museum Catalogue (1851), made Richardson's specimen the type of his genus *Mordacia*, and made two other Australian lampreys the types of his genera *Geotria* and *Velasia*.

Günther, in 'The Catalogue of Fishes in the British Museum' (1870), accepted *Mordacia mordax*, but included *Velasia* in the genus *Geotria*. Günther later gave the name *Geotria allportii* to a Tasmanian specimen. Ogilby and Regan both include this species in *Geotria australis*.

Count Castlenau (1872) created two new genera founded on immature forms, thus increasing the Australian species to six. Ogilby (1894), in 'A Monograph of the Australian Marsipobranchii,' reduced the species and genera to three. He revived Gray's genus *Velasia* and named the Australian form *V. stenostoma*, though he did not specify characters to separate it from *V. chilensis*.

Plate included *Velasia* in *Geotria*, but separated *G. stenostoma* from *G. chilensis*; he considered that both occur in Australia.

Regan, in 'A Synopsis of the Marsipobranchs of the Order *Hyperoartii*' (1911), placed the Australian species in *G. stenostoma* and restricted the species *G. chilensis* to South America. He created a new species (*G. saccifera*) for a New Zealand specimen of the pouched form.

An examination of forty-six specimens of lampreys in the University Museum and National Museum, Melbourne, showed two species of *Mordacia*, and that a new species of *Geotria* is required for specimens intermediate between the broad-headed, pouched form and the narrow-headed *Velasia* form; as these connect the two extremes it is unnecessary to retain *Velasia* as a separate genus.

The great variation in the chief characters, and the small number of lampreys available for examination, are undoubtedly the chief causes of the creation of so many species, and the discarding of these by subsequent workers.

The horny teeth are easily removed and the appearance of the mouth after their removal is different. The state of distension of the mouth revealing the whole of the teeth or the points only of the tongue teeth and supraoral teeth is important in determining the appearance of these structures. Even the teeth of the supraoral laminæ, a generic characteristic, at least, vary. Plate figures a *Geotria* with five cusps instead of four on the supraoral lamina. One *Mordacia* examined has four pointed cusps on one lamina, while the lamina of the other side has three. Castlenau said: 'I find the greatest difficulty in the determination of the Victorian fishes of this family. . . . The most important character, the dentition, seems to be subject to the most extraordinary variations; in fact, I cannot find it exactly similar in two specimens.'

Regan used the relation of the length of the first dorsal fin to the distance between the two dorsal fins as one of three distinguishing characters. In six specimens of *Geotria chilensis* taken alive during an eel fare at the Hopkins River Falls near Warrnambool, the interspace varied from ·6 of the length of the fin to 1·3 times the length, a variation of over 100 per cent. Regan used this as one of three variable characters when separating nine specimens of *Geotria* into four species.

Ogilby regarded the presence of pores on *Velasia* as a generic character. Pores occur on all the specimens of *Geotria* and *Velasia* examined. On one large pouched *Geotria australis* the pores form a definite 'lateral line.' Plate figured pores on each species he recognised.

The pouch is a puzzle. It is not a secondary sexual character for it occurs in both sexes.

It seems necessary to recognise five species of Victorian lampreys.

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5. *Notes on the Ringing of Birds.* *By* E. D. DE HAMEL.

Aluminium bands of different sizes stamped with the address 'Witherby, High Holborn, London,' and also bearing a distinctive number, are bent into an

open-sided ring which can readily be passed over the tarsus of a bird and closed, taking care that it can move easily between the foot and the knee, and the bird is then released.

The species number, date, locality, and circumstances are recorded on a form supplied with each packet of twenty rings. These rings are issued by Messrs. Witherby to subscribers to their magazine 'British Birds' who are willing to assist, and are carefully registered.

When one of these marked birds is recaptured and the incident reported the information is added to the register, and from these details an annual report with maps is prepared, and published by Messrs. Witherby under the auspices of the British Ornithologists' Club, the eighth, for 1913, being now ready. Thus the ultimate course and length of bird migration will be defined.

It is requested that all wild birds may be ringed, as it is found that even the most constant varieties wander to considerable distances.

A very large number of rings have been utilised, and about five per cent. of these retaken and reported. In addition to the English scheme, this work is being carried on by Professor Mortensen from Viborg in Denmark, and by others in Germany. The results are most encouraging. Adult swallows marked in pairs have been traced from Ayrshire and Staffordshire in England to Natal and the Orange Free State in Africa, and back to Staffordshire, but in each case only one of the pair has been retaken as they always have new mates.

Nestlings seldom return to their birth-place. Thrushes, blackbirds, and robins marked in England have been recaptured in Ireland and France. Cormorants, nestlings from Wexford in Ireland, in Finisterre, Brittany, Portugal, and Spain; mallard and wild duck in France; a pochard I marked in Warwickshire was retaken six months later at Butzow in Mecklenburg; a turtle-dove in Portugal.

Abroad the same work has been carried on since 1898, and a starling from Russia reached Yorkshire; a widgeon from Denmark reached Wales; tufted duck from Finland reached Ireland, and a Prussian black-headed gull was recaptured in Norfolk.

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6. *Report on the Biological Problems incidental to the Belmullet Whaling Station.*—See Reports, p. 125.

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7. *Report of the Committee on the Marine Laboratory, Plymouth.* See Reports, p. 163.

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8. *Report on the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 162.

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9. *Report on the Position of the Antarctic Whaling Industry.* See Reports, p. 123.

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10. *Final Report on Experiments in Inheritance.*—See Reports, p. 163.

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11. *Report of the Committee on the Nomenclator Animalium Genera et Sub-genera.*

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12. *Report on the Feeding Habits of British Birds.*

13. *Report on the Inheritance and Development of Secondary Sexual Characters in Birds.*

14. *Report on Zoology Organisation.*

15. *Report on the Formulation of a Definite System on which Collectors should record their Captures.*

16. *Report on a Natural History Survey of the Isle of Man.*

WEDNESDAY, AUGUST 19.

The following Papers were read:—

1. *On Scent-Distributing Apparatus in the Lepidoptera.* *By* F. A. Dixey, *M.D., F.R.S.*

It is well known that certain specialised scales found in various situations on the wings, bodies, and limbs of Lepidoptera are concerned in the distribution of a scent, which in many cases is characteristic of the species. These scales may occur in both sexes, but certain forms of them have only been found in males; among these are the plume-scales of the Pierines and Nymphalines. The Pierine plume-scale often affords a ready means of identifying the species, and is frequently of service in throwing light on questions of affinity. Thus, the interesting butterfly *Leuciacria acuta* Roths. and Jord., recently discovered in New Guinea, has been considered by some authorities to be nearly akin to the African genus *Pinacopteryx*, and by others to the Australasian genus *Elodina*. But the scent-scales with which it is abundantly furnished bear no resemblance to those of any *Pinacopteryx*, while *Elodina* appears to be entirely devoid of these structures. On the other hand, the scent-scales of *Leuciacria* strongly recall those of *Delias*, a genus well represented in the Australian Province, and especially so in New Guinea. Scales of a somewhat similar character are also found in *Huphina*, another genus with an Oriental and Australasian distribution, and probably not far removed from *Delias* in point of affinity. In a further structural feature *Leuciacria* is nearer to *Huphina* than it is to *Delias*, and it may possibly turn out to be a connecting link between these two assemblages. But from the evidence of the scent-scales it seems safe to conclude that such resemblance as exists to *Pinacopteryx* and *Elodina* is only superficial. The well-known 'battledore scales' that occur on the wings of Lycænids furnish a means of separating two species, *Plebeius ægon* and *P. argyrognomon*, which are often indistinguishable by ordinary methods of examination.

In some cases, though not in all, a special adaptation exists with the object of economising the scent until it is required for purposes of sexual recognition or attraction. The costal folds of the forewing in many Hesperids, noticed by Doubleday and Westwood, and first adequately described by Fritz Müller, are examples of this kind of provision. Another structural feature serving the same purpose is the collection of the scent-distributing scales into a patch on that portion of the fore or hind wing which is covered in the position of rest. This arrangement is seen in many Pierines; it occurs also in Satyrines and Nymphalines. No example of a male characterised by special scent-scales was known to Fritz Müller among the Erycinids. Such, however, do exist; as, for example, in the genera *Mesosemia* and *Pandemos*, where the scent-patches occlude one another in the attitude of rest, as notably in the genus *Dismorphia*

among the Pierines. The structure of these scent-distributors among the Lepidoptera is still to a large extent an unexplored field, and their study affords a promising subject for further investigation.

2. *Discussion on Mimicry in Australian Insects, introduced by* Professor E. B. Poulton, *F.R.S.*

It is extremely interesting to compare the phenomena of mimicry as they are exhibited in the different parts of the world. We find that the models in each tropical region are as a rule related, and often very closely related, to those of the other regions. Nevertheless, in spite of these relationships, the models commonly exhibit patterns which are peculiar to each region. Thus the *Danainæ* and their allies, the tropical American *Ithomiinæ*, always tend to be mimicked by other butterflies, although their patterns in each of the great tropical regions are for the most part very different from those in the others. The same conclusions emerge when other great groups of models are compared, and the whole body of facts affords strong indirect evidence in support of the hypothesis that mimicry is an advantageous resemblance which has grown up under the influence of natural selection.

Australia is the most isolated of all the inhabited continental tracts on the earth's surface, and its isolation is reflected in its peculiar fauna and flora. How far is it reflected in the insect-models and their mimics? Up to the present time the subject has been but little studied in Australian material, but we can nevertheless see our way to certain conclusions of much interest.

Perhaps the most widely spread models in the world are the black yellow-banded stinging Hymenoptera. The central members of these powerful combinations are wasps (Diploptera), around which are ranged sand-wasps (Fossores), and, in far smaller numbers, bees (Anthophila), followed by mimetic species of the Phytophagous Hymenoptera, and of other orders—Diptera, Coleoptera, Lepidoptera, etc. Throughout this dominant combination of models and mimics the subcylindrical body is black, encircled by many bright yellow bands. Although widespread over the world it is especially powerful in the north temperate zone. In Australia, however, its place is taken by a combination with a very distinct pattern. The bands are deep brownish orange instead of bright yellow, and they are few and broad instead of many and narrow. This pattern runs through a large and complex set of models and mimics. It is very convincing to compare such a mimetic Asilid fly as the European *Asilus crabroniformis* with the Australian species, and to observe how their very different patterns resemble those of the respective Aculeate models. An equally significant comparison may be drawn between the mimetic Longicorn beetles of these two parts of the world.

The conspicuous sluggish Lycid beetles form another dominant group of models in all the tropical regions, and here, too, a powerful Australian combination exhibits a peculiar colouring, and in some respects a peculiar constitution.

Material already received from Commander J. J. Walker in the Sydney district and from Mr. A. Eland Shaw at Healesville, Victoria, shows that the Australian contribution to the study of mimicry is sure to be of the highest interest and importance.

TUESDAY, AUGUST 18.

Joint Discussion with Section K on the Nature and Origin of Species.

See p. 579.

The following Papers were then read :—

1. *An Expedition to the Abrolhos Islands. By* Professor W. J. Dakin.

2. *Some Features in the Diurnal Migrations of Pipits, Wagtails, and Swallows, as observed at Tuskar Rock Light-Station, Co. Wexford.* *By* Professor C. J. Patten, *M.A., M.D., Sc.D.*

In certain periods of spring and autumn a stream or procession of migrants passes the Tuskar Rock Light-station daily. Owing to the barren nature of the Rock—wave-swept to a large extent in rough weather—paucity of food, and lack of fresh water, comparatively few of the travellers descend and alight. As they hasten past, the altitude of their flight relative to the level of the lantern is a matter of interest, seeing that so many nocturnal migrants strike the glass.

Most birds direct their flight towards the land, *i.e.*, S.E. to N.W. or due E. to W. Even birds presumably on emigration seem to make for the land. Pipits and wagtails travel about twenty miles an hour; swallows and martins about 90 miles an hour. On account of the very limited area of the Rock and the considerable altitude at which many of the birds fly, the descending flight for the purpose of alighting, when attempted, is almost perpendicular. Several original photographs from life of the species dealt with in this paper have been secured and used as illustrations.

Sydney.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *Dr. R. C. L. Perkins' Researches on the Colour-Groups of Hawaiian Wasps.* *By* Professor E. B. Poulton, *F.R.S.*

Dr. Perkins' researches, recorded in 'Fauna Hawaiiensis,' in 'Proc. Ent. Soc., Lond.,' 1912, p. lvi, and 'Trans. Ent. Soc., Lond.,' 1912, p. 677, have thrown a flood of light upon the evolution of colour-groups in one of the most isolated of all the land areas that afford favourable conditions for a fauna and flora. It is probable that the comparatively simple phenomena exhibited in the Sandwich Islands will be found to have a special bearing upon the infinitely more complex conditions found in the most isolated of the inhabited continents.

The only indigenous wasps of the Sandwich Islands belong to the genus *Odynerus* (in the broad sense), and Dr. Perkins concludes that the 102 species have been derived from two original immigrants a black, yellow-banded species from some unknown direction, and at a much later but still very ancient date, a black, dark-winged species probably from Asia. The latter is extremely dominant, but it found the islands already occupied, and has thus only split up into four species, as against the ninety-eight produced by the original invader.

Dr. Perkins similarly concludes that the fifty-three indigenous bees, all belonging to the genus *Nesoprosopis*, and the eighteen indigenous Fossores (*Crabronidæ*) were derived respectively from a single Asiatic immigrant bee and a single Asiatic Crabronid.

This assemblage of closely related species of wasps has formed colour-groups in the different islands, attracting also many of the species of bees and Fossores.

Kauai, the most N.W. island, possesses only one important colour-group—black, dark-winged insects with two white or yellow bands. Here the pattern of the earliest immigrant wasp was probably retained, although combined with dark wings, perhaps due to mimicry of the second immigrant. The latter on Kauai has given rise to species with yellow bands.

Oahu, the next island proceeding in a S.E. direction, has four colour-groups, of which two resemble that on Kauai in the possession by some species of pale bands, although fainter than in the N.W. island. Another group containing black, dark-winged insects is probably due to a mimetic approach towards the second original immigrant, a very abundant insect. The fourth group is much marked with red.

On Maui, Molokai, and Lanai there are three groups, one red-marked, one black and dark-winged, and one with pale bands on some of its species.

On the largest island, Hawaii, in the S.E., all the groups tend to fuse into a single large assemblage of black, dark-winged insects.

The species form structural groups of which the members, although obviously closely related, enter different colour-groups in the various islands. In other words, the colour-grouping is entirely independent of zoological affinity.

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2. *The Development of Trypanosomes in the Invertebrate Host.* *By* Professor E. A. Minchin, *F.R.S.*

If an analysis and comparison be made of those instances in which it can be claimed that the development of a given species of trypanosome in its invertebrate host is known in at least its principal traits, it is seen at once that in every such instance there is a part of the developmental cycle which is constant in occurrence and uniform in character, and another part which is of inconstant occurrence and very variable in character.

In the constant part of the cycle the parasite always assumes the crithidial type of structure and multiplies incessantly in this form to produce a lasting stock of the parasite, certain individuals of which change sporadically from the crithidial into the trypaniform type and so become the final, propagative form of the development, destined to pass back into the vertebrate host and establish the infection in it. During hunger-periods the crithidial forms may pass temporarily, in some cases, into the resting, non flagellated leishmanial form, until food is again abundant, when they form a new flagellum and revert to the crithidial type of structure.

The inconstant part of the cycle, when it occurs, is intercalated at the very beginning of the development in the invertebrate, and lasts but a relatively short time; it is derived directly from the trypanosomes taken up by the invertebrate from the vertebrate host, and takes the form of an active multiplication of the parasites in either the trypaniform or leishmanial condition. In the cases where this early multiplicative phase is wanting altogether, the trypanosomes taken up by the invertebrate host pass at once into the crithidial phase.

When a further comparison is made between the development of trypanosomes in the invertebrate host and the development of the closely allied species of *Crithidia* and *Leptomonas* which have no alternation of hosts or generations, but are confined during their entire life history to particular species of invertebrate hosts, it is seen at once that the life-cycles of these parasites of invertebrates are similar in all essential points to the crithidial phases of trypanosomes in their invertebrate hosts. It is evident, therefore, that the crithidial phase in the development of a trypanosome is to be interpreted as a reversion to, or recapitulation of, the type of development that occurred in the ancestral form which was originally a parasite of the invertebrate alone, before it had obtained a footing in the vertebrate host or had acquired the trypanosome-like type of structure; while the multiplicative phases of variable character preceding the crithidial phase in trypanosome-development are to be regarded as having been intercalated secondarily into the life-cycle and of no phylogenetic significance.

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3. *A Comparison of the Sizes of the Red Cells of some Vertebrates.* *By* J. Burton Cleland, *M.D.*

In searching blood-films from Australian birds for parasites, it was noticed that the red corpuscles of a heron were distinctly larger than those of the various Passerine birds examined. This led to systematic measurements of the sizes of the red cells of various Australian vertebrates. The slides examined have been all stained by 'dry' methods, wet fixation and staining methods being impracticable in the field. Experience shows, however, that this method may be relied on for the purpose in view.

Amongst the fishes, the Dipnoi have enormous red cells, those of *Ceratodus forsteri* being 39 × 23 to 25 μ. The Elasmobranchs have also large cells, varying from 18×12·5 to 23×13·5 μ Amongst Teleostean fishes the size is much smaller. The cells are also rounder. In *Therapion unicolor* they are nearly spherical in size 6 to 8 μ. Other species range from 9×7 up to 13·5×10·3 μ in a catfish.

The reptilia, snakes, lizards, and tortoises have red corpuscles ranging usually from 16 to 21×9 to 11 μ, though in some cases, as in the genus *Hygosoma*, the size tends to be smaller (14 to 16×8 to 10 μ).

Batrachians show red cells usually of from 18 to 20×10 to 14 μ.

Amongst birds, the emu has the largest (15·5 to 16·5×8·5 to 9·5 μ). The Podicipediformes, Sphenisciformes, Ardeiformes, and Pelecaniformes come next (approximately 14×8 μ.) Charadriiformes are generally a little smaller. The pigeons, hawks, parrots, kingfishers, and cuckoos come next, the kingfishers being perhaps the largest of these. In the Passerine birds there is a definite tendency to smaller cells, ranging from 10 to 12×5 to 7 μ, with the exception of the family Corvidæ, where the size approximates more to the previous group.

These figures seem to indicate that with specialisation has eventually come, both in fishes and in birds, a diminution in size of the red cells. The cumbersome corpuscles of *Ceratodus* have doubtless played a part in the gradual extinction of the Dipnoan fishes. The relationship of the various classes to each other is clearly shown in the size of the red cells.

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4. *Notes on some Australian Hæmatozoa.*
By J. Burton Cleland, *M.D.*

Owing to the geographical isolation of Australia, the study of the blood parasites of the vertebrates, especially of such as have no easy means of passing over stretches of ocean, is of considerable interest. In some cases, such as the marsupials, interesting speculation arises as to whether the Hæmatozoa found in them reached Australia (1) with the marsupials when these originally came; or (2) as parasites of the invertebrate host by a separate arrival; or (3) whether their appearance represented the adaptation in Australia of a parasite, at one time confined to an invertebrate host, to a habitat partly in the vertebrate and partly in the invertebrate host.

In marsupials Hæmogregarines have been found. Breuil has recorded in a bat the presence of a Trypanosome and of a Plasmodium. In birds, *Plasmodium præcox* has been recorded in a falcon, and a Plasmodium has been found in the black swan. Plasmodium has also been recorded in the introduced sparrow. Plasmodium seems to be rare in birds compared with the presence of Halteridium. Halteridia are common in Australian birds, and have been found in all the States with the exception of Tasmania, though they have been found on Flinders Island in Bass Straits. The appearances of the forms found vary somewhat, suggesting specific differences. Trypanosomes have been found in several species, but seem confined more especially to Queensland and northern New South Wales. With the same distribution, and often in the same infected birds, large parasites may be found in distended red cells. The parasite in the red cell is spherical and indents the nucleus of the host-cell, which is stretched over it so as to form a cap. I am of opinion that this is the intracorpuscular form of the Trypanosome with which it is usually associated, although my former colleague, Dr. Harvey Johnston, who was associated with me in first describing this form, has since referred to it as a Leucocytozoon, as does Breinl. The corpuscles are certainly not elongated in the remarkable way in which they are in infections by *Leucocytozoon ziemannii*. Microfilariæ are common in birds.

Reptiles.—Hæmogregarines are common in snakes and lizards. Trypanosomes and Hæmogregarines are met with in tortoises, as well as a Hæmocystidium. A Hæmocystidium has been met with in a gecko, and microfilariæ in the water lizard, *Physignathus lesueurii.*

Amphibia.—A Hæmogregarine has been met with in one species of frog only, Trypanosomes in several species.

Fishes.—Trypanosomes have been found in the freshwater eel and in a catfish.

5. *Adaptation and Inheritance in Silkworms.* *By* Professor OTTO MAAS.

The experiments in the feeding of silkworms on the leaves of our well-known vegetable *Scorzonera hispanica*, formerly undertaken by Harz, Tichomiroff, and others, for practical purposes, have been repeated by me on theoretical grounds, as well as by different methods.

As none of the breeds cultivated by Harz's selective method have survived, selection appears not to operate at the length of generations, and consequently the much-vexed question of the heredity of acquired characters cannot be omitted. General constitution, 'Wüchsigkeit,' plays its part as well; qualities are transferred according to now well-known laws of heredity, especially Mendel's, the breeds have to be analysed, in this regard as well, and crossings of normally fed with Scorzonera-fed are to be tried.

Hence the necessity for working on a larger scale, which I began (after some orientating experiments in 1910 and 1911, on the possibility of feeding and selecting some breeds) in 1912. The same material for breeds has to be cultivated in different places, to avoid local failures; different races of silkworms have to be tried on the same food, and different feeding on the same race (mulberry, Scorzonera, and half Scorzonera and half mulberry), in order to get a material for suitable crossings, and to produce new possibilities.

In accordance with Kellogg, in spite of all gradations, four main types may be distinguished, of which I used chiefly three (with different eggs, colours, and shape of cocoons and moth-pattern), designated here for convenience with the letters Jap., It., and T., and of these three races different gradations have been applied; for instance, Japanese freshly imported, and Japanese cultivated for years in Europe; Japanese of the wild form (*mandarina*); Italians, whose parents had been fed by myself, 1911, with Scorzonera, and others normal from the sericultural institutions; Tessin normal and with Scorzonera-fed parents, &c. Results of the 1912 feeding are, among others: (1) the It. and T., whose parents had Scorzonera, 1911, did not get well through the same treatment, but died out in spite of every care, in several localities, whereas the freshly imported Jap., It., and the normal T. sustained the new food comparatively well. (2) Still Scorzonera-fed in 1912 held together with mulberry-fed ones of the same race &c. show great differences. A much smaller percentage comes to the respective moultings, much longer time is required (fifty-six days instead of thirty six), and there is especially a long hesitating and wandering period of the big, well-fed, worm, till it begins to spin. (3) Its cocoon, however, is not inferior, either in size, density, or strength of thread. The crossings of the various breeds show marked differences in their productiveness. The capacity of fertilisation (active and passive) of Scorzonera moths, even of first-rate cocoons, is apparently much inferior (this can be verified not only by general comparison, but also by trying, for instance, the same male with different females and *vice versa*); fecundity, judged by the number of deposited eggs in the same race, is much less; in many cases the females could not fasten their eggs (though that was here not a race character). Also of the fertilised eggs many more decay than in normal egg-deposits, and of the remaining a much smaller number is able to hatch in the next year (*v. infra*).

All these damages are most significant, if both parents are Scorzonera-fed (thus a number of possibilities are at once excluded from further propagation), while in the case where one parent was normally fed the mating could be as fertile as a normal one. In 1912 all possibilities of race-crossings and treatment were tried (a distinction also was made if the male had Scorzonera and the female mulberry or *vice versa*), altogether over thirty, which formed the starting material for 1913.

Of these egg-deposits single ones always have been selected (to work on 'pure lines' for other purposes, of which I shall give an account elsewhere),

but of the remainder a number were always of equal descent regarding race, food in male and female, &c. Those have been united respectively, to form 'populations,' and such populations have been divided and distributed again in 1913 in different localities, and also with different gradations of food, so that last year more than thirty different breeds on different treatments, altogether more than a hundred, have been raised by myself and by my assistants.

In spite of the local dispersion or just on account of its impartiality the result has been very uniform. Almost all the breeds resulting from both Scorzonera-fed parents, even the well hatched, caused much more difficulty in raising with Scorzonera again, died out, or came to spin only in small percentage, while the Scorzonera × mulberry or mulberry × Scorzonera breeds showed a strong advantage and combined, so to say, the 'adaptation' of one parent with the healthy state of the other (still more some of the half-Scorzonera, half-mulberry-fed combinations), and seem to be superior to pure mulberry descendants in strength, and in faculty of going through the Scorzonera treatment to spinning. (That may be valid, of course, only for a certain number of the offspring, which number follows the Mendelian law.)

Whether really 'crossing favours adaptation' can be decided by this year's (1914) breedings; a further gradation prepared by corresponding copulæ of 1913. These copulæ have been tried as much as possible within the same race to avoid confusion, but with the utmost possible variety of Scorzonera handicapping, as the grandparents besides the parents have to be considered.

For instance, I., the 1914 breed, both parents 1913 Scorzonera-fed; (*a*) all four grandparents 1912 Scorzonera-fed; (*b*) both grandparents of one side 1912 Scorzonera-fed, of the other side Scorzonera × mulberry (= three grandparents Scorzonera, one mulberry-fed). Further gradations to male and female: (*c*) grandparents on both sides Scorzonera × mulberry-fed or on one side both grandparents Scorzonera-fed, on the other both mulberry-fed (= two grandparents Scorzonera, two mulberry-fed), but in different combinations; (*d*) grandparents of one side Scorzonera × mulberry, of the other both mulberry-fed (one grandparent Scorzonera, three mulberry-fed); (*e*) different combinations of the half-Scorzonera-mulberry grandparents (*i.e.* fed up to the fourth moulting with Scorzonera, then with mulberry).

II. Of the parents in 1913 one with mulberry (grandparents also mulberry), the other parent with Scorzonera (grandparents various gradations, *vide* I.), &c.

The results of 1914, as far as I can check them at present, have confirmed those of 1912 and 1913, giving corresponding gradations of the crossed and of the pure breeds with regard to their adaptation to the Scorzonera treatment. Of some biological results, the instincts of the young worms to attack and leave different kinds of food, their tropisms, I shall give an account elsewhere, also of some special experiments of inheritance relating to the melanism, called the 'moricaud,' to the 'sport' of 'non-spinners,' or abnormal 'atavistic' wing-patterns.

6. *Notes on Peripatus and on Australian Land Planarians.* *By* T. Steel.

TUESDAY, AUGUST 25.

The following Papers were read:—

1. *Studies on Echinoderm Larvae.* *By* Dr. T. Mortensen.

2. *On the Worm Parasites of Tropical Queensland.* *By* Dr. W. Nicol.

It is only five years ago since the study of worm parasites was taken up systematically in Australia. Earlier work had been of a desultory nature. In tropical Australia little work was done until the foundation of the Australian Institute of Tropical Medicine; since then a large and representative collection has been made. This paper gives a brief account of that collection.

The most common human parasites are the hook worms (*Ankylostoma* and *Necator*). Other human parasites are not more common than in temperate parts, while hydatids are much rarer than in other parts of Australia. The parasites of domesticated animals have not received much attention and only a few scattered records occur. The most outstanding parasite of the dog is *Dirofilaria immitis*, which infects the heart and lungs and appears to cause much mortality. In rats the characteristic parasite is the large Echinorhynch, *Gigantorhynchus moniliformis*.

The parasites of marsupials and monotremes are interesting. *Filaria* worms are fairly common in wallabies and opossums, while wallabies frequently harbour a large mass of Strongylids in their stomach. The Echidna is frequently infected with tapeworms and a curious little red, spiral-shaped Nematode hitherto undescribed. Similar Nematodes occur in fruit bats and snakes. Not the least interesting mammalian parasite is that described by S. J. Johnston from the dugong, a Trematode which possesses an entirely new type of structure.

The birds do not show many parasites that are peculiarly Australian or tropical. This is probably due to their migratory habits. The reptiles and frogs afford several forms which are typically Australian and a few which appear to be essentially tropical.

It is amongst the fishes that we find the most distinctive parasite fauna. This applies particularly to Trematodes, and it will probably be found that a large proportion of the Australian Trematode parasites of fishes represent new generic types, and in some cases perhaps new family types.

On the migration of Onchocerca *larvæ through the capsule of the worm nodule.*

The life-history of the parasitic worm which causes nodular disease in cattle still remains a mystery. A considerable amount of experimental work has been done on the subject, but few positive results have been obtained.

In 1911 T. H. Johnston published a summary of the work which had been done up to that date, and came to the conclusion that the most probable intermediary host is a mosquito, a louse, or a cattle-fly. Since that time four important contributions have been added by Australian workers. The first of these was by Cleland, who made the discovery that some calves which had been reared on Milsom Island, New South Wales, and had never left the island, had become infected with worm nodules. This showed that all the factors concerned in the transmission of the disease are present on the island, and therefore narrows the scope of investigation considerably. Cleland came to the conclusion that a biting fly or a mosquito is the most probable intermediate host.

The second paper is by Gilruth and Sweet, who concluded that fresh infection only occurred in young animals. They showed that direct infection is improbable, and formed the opinion that some biting insect is the most likely transmitter.

On the other hand Breuil performed some experiments which seemed to indicate the possibility of infection by means of water. He was able to induce larvæ to penetrate the unbroken skin and to emerge into water, where they lived a short time. His attempts, however, to infect various aquatic animals with these larvæ were not successful. Quite recently Cleland has published further observations. He found that *Onchocerca* larvæ could be ingested by the stable-fly (*Stomoxys*) and live in it for several days, but he could detect no development in these larvæ. He also discovered free adult worms in cattle, making their way through the tissues of the hind leg from the foot upwards.

It was with the view of confirming Breuil's experiments that the present work was undertaken. The technique employed was similar, but various modifications were adopted to ascertain the effect of temperature, rainfall, &c. In none of the thirty experiments, however, was any positive result obtained.

The procedure consisted in applying sterile water on a calico pad or in a glass vessel to the shaved skin over a nodule, and examining the water a few hours later. The negative results obtained in these experiments show that some factor was lacking which was present in Breuil's investigations.

Further experiments were performed with nodules excised from slaughtered cattle. These nodules were immersed in water under varying conditions for

different lengths of time, and both the water and the nodule were examined thereafter for the presence of larvæ.

The earlier experiments were not very successful, but they showed that a few larvæ could make their escape from the nodule into the water. Later experiments, however, showed that the larvæ could emerge through the worm capsule in large numbers, and fairly continuously for some time after the death of their host.

The effect of acid and alkali was tried, but they did not appear to stimulate the emergence of the larvæ from the nodules. Increase of temperature also was not found favourable.

All the nodules used were carefully examined both before and after the experiments to ensure that no tear or rupture was present in the capsule. Damaged nodules were rejected.

In further experiments of the same nature certain nodules were fixed after varying periods of immersion in water, and thereafter cut into serial sections. In most of the nodules larvæ were found in considerable numbers in the wall of the capsule. Usually they were uniformly distributed in one or more layers, corresponding to the denser strata of the capsule. The impression was received that the water had some definite effect upon the worm mass inside the nodule, stimulating the larvæ to make their escape through the capsule. This effect was not usually produced until after several hours' immersion.

It is worthy of note that the adult worms were found to live for more than two days after removal from this host, and that living larvæ continued to escape from the capsule for at least three days. Attempts to keep the larvæ alive in water were not successful, as they did not survive for more than forty-eight hours at room temperature.

The results of these experiments go to show that *Onchocerca* larvæ can and do make their escape through the capsule of the worm nodule, usually in small numbers, but at times or in some cases in comparatively large numbers. These results do not necessarily support the theory of water-borne infection, but they show that, even if the infection be insect-borne, it is not necessary to suppose, as has been done, that at some period of its life the worm sheds its larvæ into the blood stream. The numbers of larvæ escaping from the nodules are sufficient to ensure a moderate chance of infection in any biting insect. The fact that the larvæ may be induced to penetrate the unbroken skin by the application of water may be merely an accident, but it shows that the larvæ find their way very close to the surface, and may therefore be very readily ingested by any biting insects.

3. *Joint Discussion with Sections C, E, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.*

Sir DOUGLAS MAWSON: I propose to deal particularly with recent geographical advances in Antarctica and to lay special stress upon the work which has been performed by the Australasian Expedition. We are now all satisfied that there is a great continent at the southern extremity of the world. Possibly, were the ice to be melted, there would be, not one large land unit, but several. We feel sure, however, that there would be at least one large elevated piece of land in the Australian Quadrant,[1] but there are many who hold that there would be at least a second piece represented by the land south of America, sometimes called West Antarctica. It is, indeed, probable that this latter mass would be found to be split up into a number of small isolated fragments.

South Victoria Land and the Ross Sea Region have been explored or touched upon by eight expeditions, of which several, particularly those of Scott, Shackleton, and Amundsen, have accomplished important land work. In Victoria

[1] For convenience the Antarctic Regions may be considered as divided into four Quadrants, commencing from the meridian of Greenwich, and each named after the lands or seas to the north: hence, African Quadrant, Australian Quadrant, Pacific Quadrant, and American Quadrant.

Land the continent rises to great heights, at least 12,000 or 15,000 feet being visible from the sea. Indeed, Amundsen reports finding mountains up to 19,000 feet in height near the Pole itself. Little was known of the extension of the continent to the west of Victoria Land until recently, when the Australasian Antarctic Expedition visited that region. Two expeditions in 1840, one French and one American, spent a short time in those seas, but neither landed upon the mainland, though the French reached a rocky islet off the coast. They both saw parts of the mainland, but their reports were vague, and served only to stimulate interest in that portion of Antarctica.

The 60 degrees of that portion of Antarctica to which we sailed some three years ago then presented really a virgin field. Now we have brought back the information that it is continuous land, and that it is covered by a very thick and solid ice-cap, which flows out from the central portions of that high continent. In that portion the coast-line is not anything like so steep and precipitous as on the Ross Sea side. The German Expedition of 1901 made the land at what they called Gaussberg, just to the west of the Australian Quadrant. Their ship was frozen into the pack some distance from the land, and they sledged to the latter during the winter, but time did not permit of any extensive land work. The Swedish Expedition in 1901 and several French expeditions since then have done very good work south of America, amplifying the outline already started in that region long ago. A joint British and Swedish Expedition in the course of preparation proposes to carry on the work in that locality. The Scottish Expedition of a few years ago sighted the continental ice-sheet at what they called Coats Land, in the Weddell Sea. There it is a steep, straight ice-face—nothing but ice—which rises inland to considerable heights. The German Expedition of 1911, the same period as our own expedition, reached what appears to be the southern extremity of the Weddell Sea, and actually sighted rocky land beyond the ice coast. However, they were prevented from doing any land work. It now remains for future expeditions to tell us exactly what exists south of the Weddell Sea.

Of the African Quadrant practically nothing is known. It has been sighted only in one place—Enderby Land—by a whaler in 1820. Though the discovery of Enderby Land has not since been checked, I feel certain of its existence, after comparing the meteorological conditions logged by Briscoe in that neighbourhood and those met by us off Adelie Land in the same latitude further east. The Pacific Quadrant also is almost a blank, nothing being known excepting King Edward Land on the extreme west.

After surveying the geographical data available we conclude that there is about the South Pole a continent of about 5,000,000 square miles in area. It consists almost entirely of a great ice-cap, rocks seldom out-cropping excepting actually upon the coast.

I will confine my subsequent remarks to the 60° of the Australian Quadrant entered by our own expedition. The voyages of the S.Y. *Aurora* are so numerous that, to save confusion, I shall refer only to the more important. In Macquarie Island, a subantarctic possession of Tasmania in 55° S. lat., we had a party of five stationed for two years, making a complete examination of that fascinating island, and sending up to Australia by wireless regular daily weather messages. Adelie Land was the situation of our main Antarctic base, where eighteen of us wintered and carried out a general scientific and geographical programme for two years. When the wireless was working well, messages were sent up to Australia by relaying through Macquarie Island. About 1,100 miles west of the Main Base station was our western Antarctic base, under the charge of Mr. Frank Wild. The party consisted of eight men all told. As the ship had not been able to reach solid land in that vicinity, on account of solid floe-ice, the party had wintered actually on a floating shell-ice formation—the Shackleton Ice-shelf—seventeen miles from new land, called Queen Mary Land. Between the two Antarctic bases much new land had been met by Captain Davis. In other places the ship sailed over what had been marked as land from vague reports of the early explorers. In 1840 mapping was necessarily rougher than at the present time, but Wilkes particularly exceeded the allowable errors in his charting. I have come to the conclusion that Wilkes's mistakes have arisen from errors of judgment in mistaking solid pack-ice for

land. It is not difficult to fall into such errors, but an appreciation of the possibility of such errors leads one to wait until further proof is obtained before stating that any apparent landfall is actually land. The mirage effects, when looking over pack-ice, are sometimes very misleading. There is no time to deal in detail with the errors discovered in Wilkes's charts. Only in one place, Adelie Land, did we find land where shown on the American charts. In several other places the existence of land was disproved. Elsewhere the ice conditions were adverse, so that we were not able to penetrate as far as Wilkes, with the result that several of his landfalls still call for confirmation. Though Captain Davis was not able to push the ship sufficiently far south to get a view of Knox Land, strong confirmation of its existence is afforded by the data acquired by us on land and sea in that neighbourhood; in fact our soundings show that even if Wilkes's landfalls between Adelie Land and Queen Mary Land be out, the borders of the continent will be found not far to the south.

[Then followed further reference to the work of the Australasian Antarctic Expedition, profusely illustrated by means of lantern slides, some of which were colour-photographs. The points dealt with were the following:—

1. Extensive sledging journeys in Adelie Land, King George Land, and Queen Mary Land; the aggregate of all journeys, including supporting parties, exceeded 4,000 miles.

2. The use made of wireless telegraphy to fix a fundamental meridian in Adelie Land.

3. The continent south of Australia is of the nature of a high plateau, rising to 3,000 feet within twenty miles of the coast, but continuing steadily to rise further to the south. The coasts are, for the most part, of the nature of ice cliffs, where the ice-cap at the water-front still rides on a rocky bottom. Only occasionally do rocky capes break the icy monotony.

4. Floating extensions of the land-ice are met with at intervals, sometimes as tongues from the valley depressions of the borders of the continent, at other times as immense aprons. The most notable of the latter, named the Shackleton Shelf, extends 180 miles from the land.

5. A fringe of rocky or ice-capped islets is a feature of much of the coast.

6. The Continental Shelf is remarkable for its inshore trough: this appears to be a regular feature. As one passes out to sea the water at first deepens, then shoals, before finally plunging down into the ocean depths.

7. The ship's party carried out extensive oceanographic investigations, including a large number of deep-sea soundings.

8. Biological collections were made at each of the three land bases and from the ship; dredgings were made in depths down to 2,000 fathoms. On land the eggs of the Antarctic petrel and of the silver-grey petrel were found for the first time, and several new birds and their eggs were added to the collection. On Macquarie Island a special study was made of sea-elephants.

9. The rocks of Adelie Land and Queen Mary Land proved to be chiefly very ancient gneisses and schists. At Cape Hunter in Adelie Land an ancient sedimentary series, in part phyllites, is to be seen. On the coast of King George Land there extended for many miles rocky cliffs 1,000 feet in height; the upper half is columnar dolerite, below is a sedimentary series containing bands of coal and carbonaceous shales. Woody matter was dredged up at several points along the Antarctic coast. At Macquarie Island the rocks are chiefly igneous—for the most part gabbros. Everywhere the island has been overridden by ice, leaving behind many small glacial lakes and a mantle of till.

10. The simultaneous records obtained by three stations, each about 1,000 miles apart, and all in an entirely new sphere, from which no figures have before been returned, will prove of great value when worked up. The weather conditions at Macquarie Island were 'wirelessed' up to the Commonwealth Weather Bureau every day for two years. During a part of the time it was found possible to do the same from Adelie Land. In Adelie Land the most terrific climate ever recorded was found to prevail. The average wind velocity for the year was found to be 50 miles per hour. It sometimes blew at 90 miles per hour for 24 hours; velocities of over 100 miles per hour were often reached, and on one

occasion 116 miles were recorded in a single hour. When the wind came down in cyclonic gusts it often exceeded a puff velocity of 200 miles per hour. The instrument used for ascertaining the average hourly velocities was the self-recording Robinson cup-anemometer.

11. An unusually extensive magnetic record was obtained, including continuous magnetograph curves at Cape Denison for a period of eighteen months. This station is the nearest yet established to the South Magnetic Pole. A series of careful field determinations were made to within a few miles of the Magnetic Pole. Systematic observations of the Aurora Polaris were made in conjunction with the magnetic and wireless observations.

12. In Adelie Land special account was taken of bacteriology.]

Mr. Griffith Taylor: The present brief account of my work on Captain Scott's Expedition deals with regions near 78° S., extending from Granite Harbour to Mount Discovery.

The walls of all the glacial valleys, as well as the mighty Scarp of Lister, show a series of stages of glacial sculpture which are believed to illustrate a process of evolution. Snow-slopes give rise to *couloirs* which can be seen passing into rounded forms or 'half-funnels' (in Granite Harbour) and so into true cwms (or cirques). In suitable localities (such as below Mt. Lister) headward erosion has changed a cwm into a 'finger valley.' These with other higher cwms tend to form a radiating system resembling the relation of the fingers to the knuckles of a hand.

Great glacial troughs or Trog-taler are well shown in the Ferrar and Taylor Valleys. The latter is free from snow or ice for twenty miles; and it is crossed by several barriers or 'Riegel.'

Examples of erosion by planation arise rarely under present circumstances. Most of the glaciers are comparatively free from débris and their drainage waters are clear instead of milky. Striæ are infrequent. There is much water during summer, as along the Koettlitz Glacier, which is drained by the twenty-mile long Alph River.

The glaciers exert little pressure at their sides, and are usually bounded by a lateral moat, often over a hundred feet deep. Wind, water, and 'freeze and thaw' are potent agents here in carrying off the results of erosion, which is chiefly due to 'freeze and thaw.'

The Riegel (bars) of the Taylor Valley closely resemble those of the European Alps. The largest is 3,000 feet high and almost blocks the Valley where the latter is four miles wide. A narrow defile 1,600 feet deep and about 400 yards wide is cut through its northern end; like the defiles of Bergun, Faido, Mesocco, &c., in the South-East Alps.

The cwm and finger valleys are bounded by steep ridges 1,000 feet high (as at Devil's Bowl and Davis Valley). They could not be cut out by normal glacial erosion; moreover, they are often only a mile or two in length.

It is suggested that the '*palimpsest*' theory welds these two difficulties of Riegel and cwm erosion. The cwm erosion headward cutting occurred first, possibly, along pre-glacial valleys, and cut out finger valleys and steps, which later were overwhelmed by true outlet glaciers flowing out from the Ice Plateau. Thus the Riegel are relics of the old cwm-heads. The basins were excavated by nivation round the slowly receding snouts of almost stagnant glaciers.

The by-gone separation of the Ferrar and Taylor Valleys is described, though now they are apposed in Siamese-twin fashion.

Professor T. W. Edgworth David: In regard to Mr. Taylor's able exposition of cwm erosion, I think he has proved his point, for many of these valleys which have been so deeply recessed into that huge strip of land which may be called the Antarctic 'horst.' I would suggest, however, that we must not press that cwm theory too far. We must expect, and really do find, evidence of transverse faulting in the so-called 'Beacon Sandstone' formation. The Beardmore and the Mackay glacier valleys represent, to my mind, regions of cross faulting and downward slipping which have produced low points in the horst, sagged areas forming in the great rampart of the range low gaps through which the inland-ice has overflowed into Ross Sea. In the case of the main

outlet valleys, I do not think that we should ascribe their whole excavation to the work of own glaciers. I do not know whether Mr. Taylor would press for that. These main valleys seem partly tectonic, partly glacial, and very possibly, in their earliest inception, partly fluviatile.

Next, in regard to the Great Ice Barrier, the Ross Barrier—the huge equilateral triangle with sides about five hundred miles in length—is fed by a very large number of glaciers. It has been said by some that it is merely sea-ice thickened by additions of annual snows going on for thousands of years, until at last a thick mass results of sea-ice at the base, while the snows and névés of a thousand or more years form the remainder of its bulk. I would point out that if that were the case, we would surely expect the Ross Barrier to have a pretty even cliff facing the ocean. But we do not find that condition at all; we find it is very variable in height—from twenty feet in some places to a hundred and fifty feet in others. As this thickness is so extremely uneven, it seems to me probable that the Ross Barrier is composed, certainly in its inland portion, and probably in its sea face, of the fanned-out ribs of glacier-ice derived from the contributing glacier valleys which pour into its sides, both from the south-east and from the south-west. I think, then, that this great variability of thickness is proof that there is something more than mere sea-ice and old névé deposits (not but what the latter is an important contributor) helping to form that wonderful ice-mass, which was, perhaps, paralleled by the Pleistocene North Sea ice sheet of Europe, which impinged upon the shores of Yorkshire, and produced those big lakes near York itself.

Next the question has been raised as to whether the land-mass of Antarctica has been fixed at the South Pole from early geological times, or whether it has migrated. In Cambrian times we know that there was an extensive development of the Archaeocyathinæ limestones. These have been described by Mr. Taylor. Quite lately great blocks of Archaeocyathinæ limestone, dredged by Dr. W. S. Bruce from depths of about 1,700 fathoms to the north of the Weddell Sea, have been identified as such by Dr. Gordon. There is evidently a great development of these Archæocyathinæ limestones both on the Australian and on the American side of Antarctica. Mr. Taylor has shown that the Archæocyathinæ never extended into the tropical portions of the world, and on the whole were, therefore, probably inhabitants of cool waters. This evidence suggests that the axis of rotation of the earth, so far as the Southern Hemisphere, and probably the Northern Hemisphere too, are concerned, was perhaps approximately where it is now, even as far back as Cambrian time. One cannot, of course, press this statement until a great many more localities for the occurrence of the Archæocyathinæ have been identified. The problem of the occurrence of a Permo-Carboniferous flora within 5° of the South Pole itself will no doubt be touched upon by Professor Seward.

In regard to the possible biological analogue of modern Antarctica with Permo-Carboniferous Australia it may be stated that in Antarctica we find an abundance of the 'sea mats,' a feature which attracted special comment as far back as the date of Sir James C. Ross's Expedition. Similarly, we find that Fenestellidæ are very common in our Permo-Carboniferous beds, both in the Lower and Upper Marine Series, both of which are partly glacial in origin.

In the Antarctic we find a large pecten, *Pecten Colbecki*, enormously abundant in the raised beaches, where it dominates every other form of mollusc. Also in Antarctica we find that sponge spicules are extraordinarily abundant; indeed, the floor of the Ross Sea must be as white as snow with sponge spicules. In the Permo-Carboniferous rocks of N.S. Wales large Aviculopectens are very numerous, and sponge spicules not uncommon.

A point which I wish to emphasise because it is perhaps new, is that in our Permo-Carboniferous rocks we have a widespread development of curious mineral in our marine semi-glacial beds, to which we have given the name of 'glendonite.' This glendonite is associated with glacial erratics; we find it particularly in our Upper Marine Permo-Carboniferous rocks. It is a pseudomorph after glauberite. Sir Thomas H. Holland tells us that, in Lake Sambha in Rajputana, soda sulphates, with a little sodium chloride, are concentrated and thrown out in the water in winter, on account of the sulphates being less soluble in cold water. Mr. H. T. Ferrar, to whom members of the Shackleton

Expedition are very deeply indebted for his valuable work on geological Antarctica, has shown that soda sulphate, mirabilite, now crystallises out in Antarctica, as confirmed by my colleague, R. E. Priestley. It is only in our Permo-Carboniferous rocks, where we obtain indications of ice action, that we also find these glendonites; therefore it seems to me that, inasmuch as they were developed in association with glacial erratics, probably the water at that time was very cold.

Next I should like to emphasise the fact that Antarctica is meteorologically a great force centre, and that its presence in the Southern Hemisphere is of the utmost importance to the inhabitants of Australia, not only for the understanding of the past distribution of animals and plants, but particularly from the point of view of meteorology. There can be no question that if Antarctica were wiped off the map now, there would be much less stirring up of the atmosphere in the Southern Hemisphere than there is to-day. There is no doubt that Antarctica acts as a great refrigerator of the atmosphere, causing a steady down-draught, and it is on this account that it is a big factor in Australian meteorology.

In conclusion, may I state that I consider Sir Douglas Mawson has done a great work for science in establishing the meteorological wireless station at Macquarie Island, now taken over by the Federal Government? When one thinks of the great benefit that results from the more accurate weather forecasting made possible by this station, forecasting on the accuracy of which not only so many industries but the very lives of our sailors depend, one feels that all the money expended on Antarctic expeditions, all the hardship and suffering, and even loss of heroic life, that they involve, are justified by the gain to scientific knowledge in the service of humanity.

Professor PENCK: I desire only to make a few remarks as to the geological structure of Antarctica. It seems to me there is a very great difference in the geological structure of the western and eastern parts of Antarctica. Along the Beardmore Glacier there is no trace of mountain-making by folding since the Palæozoic age. On the other hand, the region south of South America has the structure of the Andes, and it has been shown that there are the same rocks in the western part of South America as in western Graham Land, and a very similar section of Mesozoic rocks in Patagonia and in eastern Graham Land. We see in Australia the counterpart of eastern Antarctica. How are these two parts of Antarctica joined together? I think this is still a very open question, and one which offers a wide field for future exploration.

Mr. H. T. FERRAR: Firstly, I would point out that the hill marked J on the 'Discovery' maps is separated from the foot of the Royal Society Scarp by a transverse valley which we called the Snow Valley. On a sledge journey up the Blue Glacier we were able to look along this valley and recognise Mount Kempe standing at its southern end: on a journey to the summit of Brown Island we were able to see into this valley over the tops of the Southern Foothills which have a sharp and definite crest. One of the lantern slides just shown by Mr. Taylor exhibited a long cloud hanging as a festoon along the scarp of the Royal Society Range, and reaching from the northern foot of Mount Kempe up to the western foot of the hill J, which I think betrays the presence of this transverse valley, although its existence is denied by Mr. Taylor. I do not agree with Mr. Taylor that these 'finger-valleys,' as he terms them, head in the corries of the Royal Society Range. I think the ice-masses in them are remnants of glaciers which once had their origin on the east face of the Royal Society Range, and then pushed across the transverse valley into McMurdo Sound. The ice-masses have now slipped away from their sources, and are the 'ice-slabs' shown somewhat conventionally on the 'Discovery' maps. The late Dr. Wilson at the south end, and myself at the north end of the Southern Foothills, proved that the ice in these so-called finger-valleys does not now meet that shed from the Royal Society Scarp. I think Mr. Taylor journeyed too close in under these foothills to realise that this transverse valley really exists.

Secondly, we had the good fortune to see the Royal Society Range from several points of view, and to us it stood out as an obloid crust-block with a

transverse valley (the Emmanuel Glacier) separating it from the hinterland of this latitude.

Thirdly, the three valleys indicated on the 'Discovery' maps to the northward of the Inland Forts probably have some connection with the Wright and Debenham outlet glaciers mapped by Mr. Taylor's party on their journey to and from Granite Harbour.

With regard to the Great Ice Barrier, I agree with Professor David as to the origin of the ice of the Ross Barrier and other floating Piedmont glaciers, and hold to my view that they are due to the inland-ice draining through the outlet valleys, and crowding upon itself on the coastal platform of the continent.

[The following slides were then exhibited :—

(1) The Admiralty Range, showing fault-block ranges of mountains.

(2) The Beacon Heights, with no suggestion that the Beacon Sandstone on the sides of the Ferrar Glacier was other than a single formation intruded by sills of dolerite.

(3) The Cathedral Rocks (with granite hills in the foreground), showing the rocks in ascending order which go to build up this portion of Antarctica.

(4) The Kukri Hills—a line of junction between schists and gneisses only slightly eroded by a glacier occupying what is probably a fault-trace.

(5) A view of Knob Head Mountain, to explain the movement of the ice of the Ferrar Glacier and of the South West Arm, into Taylor Valley.

(6) The Inland Forts, rasped but hardly eroded by the ice which once passed between them from the Ferrar Glacier over into another drainage system.

(7) The channel between ice and rock at the foot of Knob Head Mountain, showing how spur-truncation is brought about by the agency of water rather than by a rock-charged ice rasp; also uplift of englacial material where two ice-streams meet.

A map of Antarctica and the Southern Seas was next referred to; the east-west folds of South Africa and Victoria (Australia) were indicated, as was also the submarine furrow between this ridge and that of the Crozets, Kerguelen, &c., and yet another furrow between this island-ridge and the main coast of the Antarctic, and reference was called to the late Dr. J. Milne's view that east-west belts of the earth's crust were more rigid than meridional belts.

Antarctica itself would seem to have been subjected to a torsional stress, which was relieved by rupture along a meridional line now marked by the steep coast of South Victoria Land. That portion embracing Coats Land, Enderby Land, Adelie Land, and South Victoria Land stood firm, while that portion now beneath the Ross Sea and including Edward VII. Land foundered; owing to gain in angular velocity consequent on the earth's rotation it foundered eastward, and slipped round in an easterly direction until retarded by some obstacle near the longitude of Cape Horn. The pressures created by this retardation probably caused the crustal buckle or Andean fold of the Graham Land region.]

Mr. F. Stillwell: At Commonwealth Bay in Adelie Land is a small rocky promontory of about half a square mile in area. Around it were found slight evidences of recent relative uplift. The rock itself was a gneissic granite, which was very fresh and showed very little surface weathering. (Samples on the table indicated the fresh character of the rock at sea-level.) Inland was another exposure of rock which, in contrast to the sea-level rock, showed marked weathering. This inland rock was similar in character to the sea-level rock, and had evidently been exposed a much longer time, and it clearly showed that the sea-level rock had not been exposed sufficiently long to weather. The ice-ablation in the winter months was considerable and amounted to about four inches, and exceeded the summer accretion. It is quite possible then, that Point Denison has been exposed within the last hundred years—a very recent change. From the accounts of the second Base Party, 1,100 miles westwards from Adelie Land, the snow-accretion seemed to be in excess of the snow-ablation. The conditions thus appear to be variable in this quadrant of the Antarctic.

Captain John K. Davis: Much has been said regarding the past and present of Antarctica; I propose to say a few words on future investigation, which will so greatly benefit by the work of those who have gone before. Land

journeys, important as they are, must be supplemented by the investigation of the coast line if we are to progress towards the completion of an outline map of Antarctica. The Antarctic Coast line has been estimated by Professor David at 15,000 miles, only 4,000 of which have been explored; it is high time that a complete circumnavigation of the Continent was undertaken and its outlines correctly laid down upon our maps.

The Australasian Antarctic Expedition under Sir Douglas Mawson may be said to have begun this work of circumnavigation. Sixty degrees of longitude in the Australian Quadrant were investigated by this expedition. When heavy pack made a near approach to the coast impossible, the aid of the sounding machine was invoked, and supplied evidence as to the probable distance of the land. As a result of the voyages of the 'Aurora,' a complete section of the sea-floor between Hobart and the Antarctic is available. This section shows the big rise 200 miles south of Hobart, where the water shoaled over 1,000 fathoms in 50 miles. This rise was traced for a considerable distance on a southerly course (about 125 miles). The least depth found on this ridge was 545 fathoms. Compared with soundings taken in adjacent waters to the east and west, which ranged from 2,700 to 1,670 fathoms, it may be conjectured that the ridge rises at least 10,000 feet above the general level of the sea-floor in the neighbourhood. The bottom for the most part is hard and rocky, but no specimens of the rock were obtained. Further south another smaller rise was indicated—investigation in this locality will probably disclose others. Improved methods, and the experience gained by recent expeditions should enable future explorers to return not only with a map of the lands they have seen, but also with a knowledge of the floor of the ocean over which they have sailed.

The work of the Australasian Antarctic Expedition ended at Gaussberg. From this point another 90° of longitude stretch westward known as the African Quadrant, the most promising field for exploration remaining in the Antarctic.

An interesting feature of the work of the Australasian Antarctic Expedition was that close to the position assigned by Wilkes to Termination Land a huge ice-formation (of the same type as the Ross Barrier) extending over 160 miles from the mainland was discovered. The seaward end of this formation was named by us Termination Barrier Tongue, its position is one of considerable interest in view of the unsuccessful attempts of the 'Challenger' and the 'Gauss' to locate Termination Land further west.

Lieut. Wilkes, in his narrative of the voyage of the 'Vincennes' wrote as follows:—'On February 17 (1840) about 10 A.M. we discovered the barrier extending in a line ahead and running north and south as far as the eye could reach [this evidently refers to a line of pack-ice]. Appearances of land were also seen to the south-west, and its trending seemed to be to the northward. We were thus cut off from any further progress to the westward, and obliged to retrace our steps . . . we were now in longitude 97° 37′ E. and latitude 60° 01′ S.' The appearance of land referred to was placed on the published charts of the expedition nearly fifty miles from the position given above and named Termination Land. Allowance being made for the difficulty of obtaining precise longitude in those days, everything points to the fact that Wilkes did sight the great ice-tongue we afterwards rediscovered.

The configuration of the great inlet in the pack-ice as shown on Wilkes's chart, and named Repulse Bay, made it evident to us that some obstruction (either land- or barrier-ice) interfered with the free passage of the pack-ice to the west; our subsequent discovery confirmed this belief, and provided the confirmation given as to the accuracy of the work of this courageous pioneer in the locality.

Professor R. N. Rudmose Brown: Professor Penck has referred to the importance of the structure of Antarctica. That, to my mind, is the chief geographical problem to be solved in the Antarctic. There has been speculation as to whether Antarctica is one land mass, or two with a strait between them. It seems to me there is no room for that strait across Antarctica, because of the discoveries by Shackleton and Amundsen of the land bounding the Ross Sea. On the Weddell Sea side discovery has left a gap in the coast line, where there is certainly room for the strait, and yet probabilities are against it.

It is in that region of the Weddell Sea where the doubtful Morrell Land or New South Greenland is placed. Without going into all the evidence regarding Morrell, this much I would like to say, that nobody has ever sailed over the position of Morrell Land, or disproved the position of it since it was first reported. Ross, a very cautious explorer, reported appearance of land about its northern extremity. The Scottish Expedition could not get into that region because of the heavy ice, but the soundings seemed to shelve towards Morrell Land. It is true that Lieut. Filchner reported that he disproved Morrell Land; however, he did not go sufficiently far west to sight it, so his statement is of no value.

The Weddell Sea has been very much neglected. The Ross Sea quarter has had great attention paid to it, probably because it is the nearest and most direct way to the Pole.

Nobody has yet landed on Coats Land, nor on Leopold Land. There was no possibility of landing on the ice-cliff of Coats Land when the 'Scotia' discovered it in 1904; but there was no doubt whatever about that ice-cliff being a part of the ice-cap pouring off the continental land. The deep-sea soundings and deposits by themselves showed that, but what I would like to emphasise is this: that Coats Land seemed to rise in the interior to great heights, but we were not certain of the distance of these heights. Most of us, and particularly those with longer sight and more experience in polar seas, were convinced that this was the plateau rising into the interior to heights of perhaps 10,000 or 15,000 feet. Future exploration will, I believe, confirm this. It is to be hoped that Sir Ernest Shackleton will be enabled to start on his trans-continental expedition, because he will score a new track across Antarctica, and incidentally will solve this problem of the structure of Antarctica towards the Weddell Sea.

Dr. G. C. Simpson: I desire to refer to only one matter connected with the Antarctic. I do not think we realise sufficiently that the southern hemisphere is much colder than the northern hemisphere, and the reason for this difference in temperature is certainly not understood by scientists. When we think of the temperature of a place, we think of the temperature in the lower atmosphere. Now the mere passage of light through the atmosphere will not warm it. The main method in which the atmosphere becomes warmed up is by the sun shining on something it can warm. Now, in the Northern Hemisphere there are large masses of land which can absorb the sun's energy, and then give the heat to the atmosphere. In the Southern Hemisphere, on the contrary, the whole mass of land within the Antarctic continent is covered with ice which is practically a perfect reflector, and therefore when the sun shines on to it a large proportion of the energy is reflected into space. I do not think scientists have quite realised how important that is—that 5,000,000 square miles of the earth's surface in the Southern Hemisphere reflect into space a large part of the energy received from the sun. I feel certain that this is one of the chief reasons for the difference in temperature between the Northern and Southern Hemispheres.

Mr. Charles Hedley: Naturalists have deduced the age, climate, contour, fauna and flora of Tertiary Antarctica from the nature of the Antarctic refugees now living in southern lands. Biologists note that many similar forms, either recent or fossil, are repeated in various southern islands or continents. For instance, there are the monotremes, once perhaps a numerous group, of which two widely different types survive in Australia, Tasmania, and Papua. The bones of other monotremes occur in South American deposits. Then there are the Thylacines, recent in Tasmania, and fossil in South America and Australia. Either we must consider that these groups arose independently in each hemisphere, or that they spread from the one to the other. In the latter case, a South Polar land offered the most direct way from home to home. The simplest explanation of the distribution of marsupials, past and present, is that they originated in South America, spread by way of Archihelenis to Western Europe, by way of the West Indies to North America, and by way of Antarctica to Australasia.

Turning to the Amphibia, both the Hylidæ and the Cystignathidæ have their chief seat in South America; both extend to Australasia, where they

are best developed in the south-east, and gradually vanish before reaching the Moluccas. Here again the most direct road between the two centres lies across Antarctica. By cumulative evidence from plants, both cryptogams and phanerogams, from animals, both vertebrate and invertebrate, of many and of varied types, we are led to the conclusion that the way they might have gone was the way they actually went.

A problem which geographers seek to solve is—whether there are now one or two Antarcticas, and again we may ask whether in the Miocene there was one Antarctica or two Antarcticas? If there was only one, why did it not distribute its faunal contents evenly between Australia and New Zealand? But if there were two, or more, did one contribute to the population of New Zealand, and another to that of Australia?

Though the fauna and flora of New Zealand are obviously indebted to Tertiary Antarctica, yet New Zealand has not received any of the vertebrates mentioned; there are neither monotremes, marsupials, Hylidæ, nor Cystignathidæ. Further, the differences are positive as well as negative. In New Zealand there is a group of earthworms, the Acanthodrilids which recur in South America, but not in Tasmania or Australia. The fuchsias, which are mostly South American, have a few outliers in New Zealand, but none in Tasmania; the bushy Veronicas are mostly from New Zealand, but there are a few in South America, and none in Tasmania.

The Antarctic constituent in the Australian flora and fauna includes both a frigid and a subtropical element. How was it that both these incompatible elements could issue from the same source? The answer offered is that then, as now, a high plateau existed in central Antarctica, where the frigid forms had their station, while the subtropical species existed on the coast. While the climate cooled, the land-link between Antarctica and Tasmania endured till the alpines in their turn followed the retreat of the subtropical forms northwards.

The conclusions reached from this comparison of southern flora and fauna are that: (1) at or about the Miocene a subtropical climate prevailed within the Antarctic circle; (2) before, during, or after this warm epoch, land extensions jutted north from Antarctica to New Zealand, to Patagonia and to Tasmania; (3) southern floras and faunas availed themselves of the opportunities for migration offered by these extensions. Relics of these migrations are our only evidence of such changes of land and climate.

Professor A. C. Seward gave a brief account, illustrated with lantern slides, of some of the fossil plants collected by members of Captain Scott's second expedition, with special reference to Dr. Wilson's discovery of Glossopteris in latitude 85° South. Fragments of well-preserved leaves of *Glossopteris indica* found in the rocks of Buckley Island, a nunatak on the Beardmore glacier, afford important evidence both as to the age of the Beacon Sandstone formation and as to a former connection between Antarctica and Gondwana Land. The geological distribution of Glossopteris in other parts of the world suggests that the strata of the Buckley Nunatak must be assigned to the Permo-Carboniferous period. In addition to Glossopteris, the Polar party found fragments of gymnospermous wood and impure beds of coal. Mr. Priestley, a member of Commander Campbell's party, obtained a large piece of petrified wood from a sandstone boulder on the Priestley glacier in latitude 74° S., which on investigation proved to be a gymnospermous stem of considerable botanical interest; the wood shows well-marked rings of growth and exhibits Araucarian characteristics, but in view of the possession of certain peculiar features it has been described under a new generic name as *Antarcticoxylon Priestleyi*. This stem, though particularly interesting from a botanical point of view and as demonstrating the occurrence of well-grown trees on the Antarctic continent, does not afford any conclusive evidence of geological age. Associated with the partially decayed tissues of Antarcticoxylon was found a winged pollen-grain, described as *Pityosporites* sp., which bears a striking resemblance to the pollen of recent Abietineæ.

In conclusion, reference was made to the bearing of these important discoveries on climatic considerations, and it was pointed out that, while there is

clear evidence of a considerable change in climatic conditions since the period when Glossopteris flourished on the Antarctic continent, there is no adequate reason to assume any change in the position of the earth's axis. Meagre as it is, the material collected by the Polar party calls up a picture of an Antarctic land on which it is reasonable to believe were evolved the elements of a new flora that spread in diverging lines over a Palæozoic continent, the *disjuncta membra* of which have long been added to other land-masses, where are preserved both the relics of the southern flora and of that which had its birth in the north.

The President (Prof. W. Bateson) then declared the discussion closed.

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4. *Heredity of some Emotional Traits.*
By Professor C. B. Davenport.

While sociologists, who lay great stress on the importance of conditions in determining human traits, have been forced to admit the hereditary basis of feeble-mindedness, they still hold, for the most part, to the view that in the moral field heredity plays little part. Both to test this view and because of the theoretical importance of the subject, the topic of inheritance of the traits of persons of the criminalistic type was undertaken.

The base of the study is the family history of 165 wayward girls in State institutions of the United States. The family histories were secured by specially trained 'field-workers,' operating in conjunction with State Institutions and the Eugenics Record Office. In addition, for the study of special topics a mass of other family histories, some 2,500 in number, was drawn upon freely.

As a general result of these studies about twenty traits were considered in some detail. Many did not yield any clear-cut results; but in at least five cases the hereditary factor was clear and evidently determined the behaviour.

1. The tendency to tantrums—or violent outbursts of temper—in adults is inherited as a dominant trait; that is, it does not skip generations. In several scores of histories it was possible to trace the tendency back three, four, and even five generations.

2. Violent eroticism, or striking lack of self-control in the sex sphere, is also a positive character, and likewise is traced back without breaking generations; and half of the offspring of a highly erotic person show similar irresistible impulses.

3. Impulsions to suicide are accompanied by depressions. In harmony with what has been shown for some types of mania-depression insanity, it appears that this depression is inherited as a recessive or negative character. It ordinarily skips generations; but the tendency is ordinarily found on both sides of the parentage of the affected individual.

4, 5. Two other traits appear, remarkably enough, as sex-linked characters. They are transmitted through mothers to some or all of their sons. They appear in daughters, typically, only when shown by the father, and the tendency is carried also by the mother. If both parents show the trait all children have the tendency to develop, in due time, the trait. These traits are dipsomania and certain other types of irresistible impulsions to drink, and nomadism, or the impulsion to wander.

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5. *The Hormone Theory of the Heredity of Somatic Modifications.*
By Dr. J. T. Cunningham, *M.A.*

Darwin's theory of the origin of species was founded on the assumption that species were divided by differences of adaptation. It may be true that allied species sometimes differ slightly in their mode of life, and show differences of structure corresponding to these differences of action; but investigation has entirely failed to prove any utility or bionomical significance for many specific and other diagnostic characters, and the assumption that such characters are due to correlation with adaptive characters is without foundation.

Mendelism in itself throws no direct light on the origin of characters; it deals merely with their transmission. It is inferred, however, by the

Mendelians that characters transmitted as units must have arisen as units, and it is certain that Mendelism has shown how loss of characters and new combinations produce new varieties or types. It is reasonable to conclude from present knowledge that non-useful diagnostic characters have arisen as the result of gametogenesis and conjugation; but the principles of Mendelism or mutation are not applicable to the phenomena of adaptation.

In the first place when we see, as in the frog, the flat-fish, or the caterpillar, adaptation to two quite different sets of conditions in the individual life, it is impossible to believe that such transformation was due to mutations not caused by the external conditions. There is no evidence that the necessary gradual changes could occur unless the conditions produced them; if so, why have they not occurred in other cases when the conditions were absent.

In the second place we have the phenomena of secondary sexual characters, of which one of the most impressive and most fully investigated is that of the antlers of stags. The Mendelian merely regards such characters as mutations which are coupled with primary sex. But primary sex is determined at fertilisation, and such secondary sex characters have been shown to be dependent on the presence and function of the gonads. Characters which are determined in the gametes are not generally affected by computations of gonads at any part of the body in after life. It has been shown that the effects of castration on the development of secondary sexual characters are due to the stimulus of chemical substances produced by the gonads, especially in their functional activity.

No hypothesis explains these facts except the Lamarckian, namely, that the stimuli involved in the use of the organ originally produced them by causing hypertrophy in the part of the soma affected, and that in course of generation the tendency to this hypertrophy was transmitted to the gametes. The hormone theory explains how such transmission may be effected. The hypertrophied part gives off chemical substances or hormones which circulate through the body, and acting on the gametes stimulate those parts of them which are destined to develop the same parts in the next generation. The transmitted effect may be infinitesimal at first, but if continued for many generations would account for the phenomena we now observe.

This, of course, would account for the transmission of all somatic modifications due to external stimuli, and a special application of the theory is needed to explain the peculiarities of functional secondary sexual characters.

In the first place the stimuli in these cases have acted only on individuals of one sex, on the males in stags, on the females in the case of the mammary glands. On any other theory a variation occurring in one sex would be inherited by both sexes unless it was coupled with primary sex, and then it would be wanting in the other sex. But antlers are not wanting in females nor mammary glands in males: they are only not developed. On the hormone theory the somatic modifications were produced at the time when the gonads were giving off their hormones, and thus the tendency which is inherited is to develop these modifications in the presence of those hormones and not otherwise. Then we can understand why the organs develop only at puberty, and often only develop during the period of sexual activity, being shed or absorbed at the end of that period and re-developed.

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6. *Some Facts regarding the Anatomy of the Genus* Pegasus. *By* Professor Hector F. E. Jungersen.

The facts, briefly condensed in the following abstract, have—for the greater part—hitherto been overlooked or unknown.

Cranial Skeleton.—Opisthotics, alisphenoids, orbitosphenoids, and basisphenoid absent; no eye-muscle canal. Posttemporal (suprascapular) forms part of the skull. Three stout infraorbitals, the middle and posterior firmly connected with the preopercle. Opercular apparatus complete. The large flat preopercle, covering most of the lower face of the head, has generally been taken as 'homologous to operculum, præoperculum, and suboperculum' (Günther), while the very small opercle and subopercle, hidden in thick skin, have completely escaped attention. Interoperculum slender, widely separated

from suboperele, only its anterior end visible from without. The prominent rostrum (much shortened in females of *P. draconis* and *P. volans*) is formed by the coalesced nasals. Pterygo-palatine bar very shortened, consisting of the palatine and only one pterygoid (ento- and metapterygoid wanting), completely separated from hyomandibular suspensorium and connected with anterior end of vomer; together with premaxilla and maxilla lodged in a precranial cavity below the base of the rostrum. Between premaxilla and maxilla is interpolated a large separate bone, corresponding to a small cartilaginous disc or meniscus found in other fishes. Front part of maxilla forming a large process projecting over premaxilla into anterior part of the subrostral chamber. Mandibular suspensorium consisting only of hyomandibular, symplectic and quadrate.—Branchiostegals 5, well developed (hitherto only one observed and described as rudimentary). Basibranchials 2; lower and upper pharyngeals with conical teeth. Hypobranchials I.-III. present; epibranchial IV. very long and stout, widely separated from its ceratobranchial. Pharyngobranchials II. and III. fused into a well-developed dentiferous plate; pharyngobranchials I. and IV. absent.

Clavicular arch consisting only of post temporal and clavicle; part of the latter enters the dermal skeleton of the trunk. *Scapular arch* and *pectoral fin* almost horizontal, their inner faces looking upwards. Foramen scapulare bounded by both scapula and coracoid; the latter with processes fastened to the ventral carapace. Articular face for pectoral rays fixed across a slit in the carapace and made up of part of the scapula and three stout basals.

Pectoral rays unbranched, but fundamentally like soft rays; they are jointed distally, stiff basally, and composed of two longitudinal parts; but owing to the horizontal position of the fin the otherwise lateral constituents in *Pegasus* are upper and lower, and instead of being equal halves, the upper is much more slender than the lower. In the so-called pectoral spines of *P. draconis* and *P. volans* the upper constituent is almost thread-like, imbedded in a furrow along the lower one, which may be extremely stout (*cf.* especially the 5th pectoral ray of *P. volans*); the original jointed condition is much obscured but always observable, and the extreme apex is always soft and distinctly jointed.

Pelvis large (to a certain degree resembling that of *Sebastes*), by means of short ligaments fastened to the clavicles. First ray of *ventral fin* a well-developed, true spinous ray (hitherto completely overlooked); one or two elongated, unbranched soft rays and a slender short one (*Pegasus draconis, P. volans, P. natans*: I+2, *P. lancifer* I+3).—*Abdominal vertebræ* 7; the anterior 6 immovably joined, devoid of ribs, provided with large spinous processes forming together a long partition, the upper margin of which (from vertebra 2 to 6) carries a modified interneural, probably representing an aborted first dorsal fin. 7th vertebra movable, provided like the 8th (the first caudal) with strong ribs (probably 'epipleurals' rather than true ribs). Number of caudal vertebræ: *P. draconis* 12, *P. volans* 13, *P. natans* 15.[1] Vertebræ 8-12 connected with 5 dorsal and 5 anal interspinous bones, all bisegmented; first and interspinous bone considerably enlarged. Last caudal vertebra terminating as a vertical plate (probably the urostyle fused with 2 hypurals), 8 caudal, 5 anal, and 5 dorsal soft, unbranched rays.

The *main longitudinal muscles* of the trunk have been modified under the influence of the immovable carapace. The dorsal and ventral portions are separated on each side by a considerable interspace, the lateral body wall consisting only of the dermal armour and its peritoneal lining; besides the anterior, part of the dorsal portion is mainly reduced to a flat thin ligament. In the posterior part of the trunk and in the movable tail the longitudinal muscles are well developed, with strong tendons inserted to the dermal skeleton as well as to the vertebræ.—*Gills* four, each a double row of leaves. *Pseudobranchia* large, with 6-7 leaves.—*Gill-rakers* small, papilliform; a slit in front of lower pharyngeal.—*Air-bladder* absent. The greater part of the contents of the body cavity lodged in front of pelvis. A large left and a small right lobe of the *liver* are connected by a narrow bridge below the alimentary canal; most of the lobes situated dorsally to the latter. The wide *œsophagus* passes into the quite straight and simple *stomach*, which again without any demarcation continues

[1] *P. lancifer* I have not had the opportunity to dissect.

in the intestine, the beginning of the latter only indicated by the entrance of the bile-duct. A gall-bladder on the lower face of the right liver-lobe. Behind the entrance of the bile-duct the intestine turns to the *left* side; after two convolutions below the left liver-lobe it runs transversely under the liver-bridge to the right side, and after two narrow convolutions it reaches the middle line and as the colon passes over the pelvis to the anus.—The *kidneys* are remarkably short, reaching from the skull over only one-third of the body cavity; urinary ducts long, urinary vesicle large, bilobed. *Ovaries* closed sacs behind the kidneys, *oviducts* short and wide. *Testes* short and narrow. The *caudal vein* divides into *two large veins* passing along the urinary ducts into the kidneys. The *aorta* follows in the trunk the right side of the vertebræ, giving off the arteria cœliaca far in front, just behind the union of the branchial arteriæ revehentes.

The facts mentioned above clearly show the *Pegasus* (1) to be an Acanthopterygian, (2) to represent at least a 'suborder' of its own, distinguished by several structural peculiarities from all fishes hitherto known (see, for example, the quite unique precranial position of the pterygo-palatine bar together with the premaxilla and maxilla, the connection of the latter bones by means of an interpolated bone, &c.). Possibly the *Pegasidæ* (*Hypostomides*) may be a strongly modified offshoot from the stem of the *Scleroparei*; but no existing mail-cheeked fish shows any closer relationship with the *Pegasidæ*, certainly not forms like *Agonus* or *Aspidophoroides*.

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7. *Acquired Habits of Muscidæ (Sheep-Maggot-Flies).* *By* Walter W. Froggatt, *F.L.S.*

At the present time the most serious enemies of the land-owners and squatters in the greater part of pastoral Australia are several species of blow-flies. Forsaking their natural food, chiefly carrion, they have acquired the habit of blowing any soiled or damp wool on otherwise healthy sheep.

All the flies in question, though well-known indigenous species common to the greater part of Australia, only learnt the value of soiled wool as a suitable place to deposit their eggs, or living maggots, within the last ten or twelve years.

Previously they were known merely as 'blow-flies.' Several kinds came into the house and dropped their eggs upon meat, or at times infested open wounds; but otherwise they were simply scavengers. Others were found about decaying animal matter in the vicinity of killing yards or butchers' shops, a few feasted upon rotten fruit and such like fermenting vegetable matter. At the present time (1914) at least four species have been bred in, and identified from, soiled wool taken from sheep running in the paddocks under exactly the same conditions that have prevailed in sheep breeding in Australia for the last twenty-five years.

Though this wool-blowing habit was unknown in this country until about twelve years ago, it is remarkable that in Great Britain, from a very early date in the records of sheep husbandry, two species of 'blue-bottles' or 'blow-flies' have been known to do a certain amount of damage in exactly the same manner to the shepherd's flocks. Though cosmopolitan in its range, *Lucilia sericata*, the common sheep-fly of Great Britain, has never been recorded as having affected healthy sheep in any other part of the world, except in one isolated case, when it was accidentally introduced with sheep into Holland. Prior to 1903 there may have been occasional cases of blown wool, under exceptional circumstances, as has been claimed by sheep-owners, when discussing the question of sheep-maggot-flies, but it was certainly a comparatively rare occurrence to find putrid blown wool. About the end of 1902 the writer first obtained samples of shorn wool containing living maggots; and in the following season they were reported doing considerable damage. Specimens were received for identification from the owners of flocks in the north, north-west, and from a large area of the southern plains.

At first the point of infestation was round the tail where the wool had been soiled with the urine, and the injury was chiefly confined to close-woolled stud ewes. Within a very short time, however, the flies found that other kinds of

damp wool were suitable, and though the sheep with the thickest fleeces and wrinkled skins are the most susceptible, no class or breed of sheep is exempt in a bad fly year. Ewes, too, were the first that suffered, but it was soon evident that both sexes were liable to infestation if weather conditions were favourable and flies abundant. Wethers are blown anywhere if dirty or damp, and lambs after tailing and marking are often so badly blown that a certain percentage die despite the greatest care; while on the large holdings in Central Queensland, where the system of marking is more rough and ready, thousands of lambs, particularly wether lambs, are blown, and in some cases might be said to be eaten alive. Rams, though they often get 'maggoty heads' from the after-results of fighting, were the last to be attacked on the body wool. But it is now quite a common thing to find a number of stud rams badly blown about the crutch, and the maggots swarming on the wool of the rump.

Where sheep are not examined constantly, and get even slightly blown, the infested area soon spreads, as other flies, attracted by the scent, keep on blowing round the evil-smelling heated wool. As these maggots increase in size they work their way down through the fibre of the wool, and, through their presence, cause the wool to become a blackened putrid mass of corruption. Finally the maggots reach the skin, where they set up an inflammation of the cuticle. The broken skin suppurates and the detached wool is torn off, or falls off. Under such conditions the sheep often wanders away from the flock into the scrub, and dies; the more robust ones recover.

In all the first samples of blown wool, whether received from the sheep-owners or taken direct from sheep in the paddocks, the writer only bred one species of blow-fly. This was the common brown and yellow blow-fly (*Calliphora villosa*), found both in the town and country, a carrion-feeder ranging all over Australia. An unusual increase in the numbers of this species was probably due to several causes; in the first instance to the enormous number of dead animals, particularly sheep, that had died during the great drought a few years before, and which, not worth skinning, usually remained covered with decaying skin and wool. This was also the time when hundreds of thousands of poisoned rabbits were festering all over the pastoral holdings—ideal carrion for the blow-flies. The next factor was the production of a new class of merino sheep, to replace the smaller smooth-bodied animals, quite a different type of larger size, closer wool, wrinkled skin, and heavy yoke all through the fine wool, much more easily soiled with urine and excreta.

With the return of the good seasons the supply of carrion vanished, but the blow-flies remained. Some had blown the dead wool, and recognised the smell of fouled wool, and thus *Calliphora villosa* became a sheep-maggot-fly. Within the year numbers of a second species of blow-fly emerged from samples of infested wool which had been sent in from the country, and placed in the breeding jars. Though the maggots were very similar, it was a very distinct species, *Calliphora oceaniæ*, easily distinguished from the first species by its smaller size, and the colouration of the abdominal segments, which, instead of being golden, have the sides blotched with yellow, and the rest deep metallic blue. The range and habits of both species are identical, and as they are frequently found together it is only reasonable to suppose that *Calliphora oceaniæ* learnt the habit of blowing wool from *Calliphora villosa*.

For several years only these two species were found in the larval state among blown wool. Though there were reports from sheep-owners that a third species was infesting the sheep, and that a dark-coloured 'hairy' maggot was busy among the wool in the western country, it was not until late in 1909 that specimens of the third blow-fly, *Calliphora rufifacies*, was obtained direct from blown wool. There was no mistaking this smaller metallic blue and green fly: the parent of the 'hairy maggot.' While both the previous species produce the typical elongate cylindrical maggot, *Calliphora rufifacies* is a shorter thickened larva having each segment ringed with a band of fleshy filaments, which have given it the popular name in the bush of the 'hairy maggot' or 'hairy maggot-fly.' Though now extending its range, until very lately this fly was not found in the coastal districts, but was confined to the inland districts of Australia.

Before *Calliphora rufifacies* learnt the habit of blowing live wool, presumably through the smell of the wool infected by the other two species, it was a carrion-

feeder in the larval state. Now its carrion-breeding habits have made it the most serious pest among all the blow-flies, for at the time when the wool on the sheep is too hot to breed maggots (in midsummer), and the other species are seldom seen, *Calliphora rufifacies* is laying her eggs on dead sheep and any offal found round the tanks and dams, and is thus always on the increase. At the present time (1914) this species seems to have taken the place of the two common house species, and to be responsible for the greater part of the damage, all over the interior, caused by the sheep-maggot-flies.

The last species to attack our sheep, and that only within the last two years, is the introduced British sheep-fly (*Lucilia sericata*), a series that is the common 'green-bottle-fly' about the coastal country. In this case we have the descendants of the introduced British sheep-fly after having lost the peculiar habit of its ancestors, again acquiring the taste from the habit of allied Australian blow-flies.

8. *Australian Trematodes and Cestodes: a Preliminary Study in Zoogeograhy. By* S. J. JOHNSTON, *B.A., D.Sc.*

Practically all the groups of vertebrate animals found living in the various zoogeographical regions of the earth harbour numbers of parasitic worms. The entozoan fauna of one of these classes of vertebrate host in any particular region is constituted by a number of species which are found to be related to others which comprise the entozoan fauna of the *same class* of vertebrate host living in some other region. For instance, the entozoan fauna of marsupials in Australia comprises a number of Cestodes (*e.g.*, species of *Linstowia*) and a number of Trematodes (*e.g.*, species of *Harmostomum*), and the nearest relatives of each of these are found in certain species of *Linstowia* and *Harmostomum* that live parasitic in South American marsupials.

The Trematodes and Cestodes of Australian birds find their nearest relatives in worms living in related birds that inhabit other parts of the world; and the Trematodes and Cestodes of Australian frogs are most closely related to those of frogs in other regions.

The entozoan fauna of the host-animals belonging to any particular class of vertebrate may be separated into two divisions:—(1) Those that have been parasitic in these hosts for a very long time—practically from the first appearance of the host-animals, and (2) those that represent more recent acquirements. The members of the former division may be readily recognised by the fact that they have near relatives parasitic in other branches of the same stock, whilst members of the latter division generally have not. The members of each genus (or sometimes of several closely related genera) in the former division, in many cases scattered all over the world, constitute a natural group, and must be looked upon as derived from common ancestors.

These ancestors were parasites of the progenitors of the host-animals in the very early days, when the group was much younger and much more restricted in its distribution than at the present time. A study of the relationships and distribution of the parasites affords some circumstantial evidence of the past movements and paths of dispersal of the host-animals.

9. *On the Emergence of the Nymph of* Anax papuensis *(Burm) from the Egg (Class* Insecta, *Order* Odonata). *By* R. J. TILLYARD, *M.A., F.E.S.*

Previous to hatching, the embryo lies with its head fitting closely under the pedicel or cap of the egg. The eyes are large and blackish, the antennæ lying between them and directed posteriorly. The clypeus, labrum, mandibles, and maxillæ can be clearly seen. The labium appears as a large paired organ directed posteriorly, and reaching well down between the legs. The legs lie directed posteriorly along the outer (ventral) surface of the embryo, except the hind tarsi, which are directed forwards. The hind end of the abdomen is bent round the posterior end of the egg, the ninth and tenth segments, with the cerci, being directed forwards. The mid-gut still encloses a large cylinder of yolk. The tracheal system can be seen, but is devoid of air.

During the three days previous to hatching, the dorsal vessel increases its pulse from about thirty to the minute to between eighty and one hundred. Just before hatching, a cephalic heart appears in the posterior head region. At first small and only pulsating intermittently, it rapidly increases in size. The pressure thus caused forces the pedicel to break away from the egg, whereupon the nymph flows easily and quickly out of the egg-shell. It emerges swathed in an outer skin or sheath, which has been called by Pierre the 'amniotic covering.' This is shown to be a non-cellular chitinous cuticle, not related to the amnion in any way. It represents, in fact, the first moult of the larva. The swathed stage may be termed the pro-nymph.

The pro-nymph stage lasts only a few seconds. The cephalic heart increases enormously, and is seen to consist of two large chambers, an auricle and a ventricle, which pulsate regularly at about thirty beats to the minute, and appears to be pumping liquid, probably blood, into the head. The latter swells quickly up to twice its original size, and thus the pro-nymphal sheath soon splits down the back of the head and thorax, and the young nymph emerges, freeing itself from the sheath by a few convulsive struggles.

The pro-nymphal sheath is seen to be made of very thin transparent chitin, and shows the complete larval form, with head, mouth-parts, and legs easily seen. It ends posteriorly in a sharp spine, which catches in the broken end of the egg, and so forms an anchor during the emergence of the nymph.

The cephalic heart quickly subsides in the free nymph. Meanwhile, a smaller pulsating chamber has appeared between the rectal valves. While the cephalic heart is forcing the blood into the head, this rectal pulsating organ appears to be pumping water into the rectum. As soon as the nymph is free, its pulsations increase to about eighty per minute, and water is violently forced into the rectum, so that the whole beautiful branchial basket is quickly distended and brought into view. Meanwhile, the tracheal system, which, at the time of hatching, only contained air anteriorly to the mid-gut, is seen to be steadily filling with air. The air travels slowly down the dorsal tracheal trunks and gradually fills the numerous branches, finally entering all the tiny tracheoles of the rectal gills. Afterwards, rectal breathing proceeds regularly.

The young nymph is transparent except for the eyes and the dark plug of the mid-gut. It has two sharply pointed cerci, but the superior appendage is only rudimentary. In a few hours the nymph darkens all over to dull green or blackish. It is suggested that the rupture and atrophy of the amnion described by Brandt in the embryology of Odonata is due to the formation of the pro-nymphal sheath or cuticle, which forms a close-fitting and far more effective protection for the embryo, besides allowing for the early beginning of the process of excretion through the formation of a chitinous exoskeleton.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION.—SIR CHARLES P. LUCAS, K.C.B., K.C.M.G.

The President delivered the following Address at Adelaide on Wednesday, August 12:—

Man as a Geographical Agency.

IN an inaugural address to the Royal Scottish Geographical Society on Geography and Statecraft Lord Milner said: 'If I have no right to call myself a geographer, I am at least a firm believer in the value of geographical studies.' I wish to echo these words. I have no expert geographical knowledge, and am wholly unversed in science, but I am emboldened to try and say a few words because of my profound belief in the value of geographical studies. I believe in their value partly on general grounds, and largely because a study of the British Empire leads an Englishman, whether born in England or in Australia, to the inevitable conclusion that statecraft in the past would have been better, if there had been more accurate knowledge of geography. This statement might be illustrated by various anecdotes, some true, not a few apocryphal; but anecdotes do not lend themselves to the advancement of science. I am encouraged, too, to speak because the field of geography is more open to the man in the street than are the sciences more strictly so-called. It is a *graphy*, not a *logy*. Geology is the science of the earth. Geography is a description of the face of the earth and of what is on or under it, a series of pictures with appropriate letterpress and with more or less appropriate morals to adorn the tale.

Taking the earth as it is, geographical discovery has well-nigh reached its limit. The truth, in the words of Addison's hymn, is now 'spread from Pole to Pole,' and recent exploration at the South Pole, with its tale of heroism, will have specially appealed to the citizens of this Southern land, reminding us all that the age of chivalry is not yet past. The city of Adelaide is rich in the record of explorers, and to the list is now added the name of Sir Douglas Mawson. It is not for me to attempt to take measure of his great enterprise, but the scientific results of his work, including the carrying of wireless telegraphy into the Antarctic Continent, illustrate my thesis that man is a geographical agency. Members of the British Association will note with pleasure that he derived backing and inspiration from the Australasian Association for the Advancement of Science. Outside the polar regions coasts are in most cases accurately known. The age of Cook and Flinders is past. Interiors are more or less known. In Africa there is no more room for Livingstones, Spekes, Burtons, Stanleys. In Australia Sir John Forrest is an honoured survival of the exploring age—the age of McDouall Stuart and other heroes of Australian discovery. The old map-makers, in Swift's well-known lines, 'o'er unhabitable downs placed elephants for want of towns.' Towns have now taken the place of elephants and of kangaroos. Much, no doubt, still remains to be done. The known will be made far better known; maps will be rectified; many great inland tracts in Australia and elsewhere will be, as they are now being, scientifically surveyed; corners of the earth only penetrated now will be swept and garnished. But as we stand to-day, broadly speaking, there are few more lands and seas to conquer. Discovery pure and simple is passing away.

But meanwhile there is one side of geography which is coming more and more to the front, bringing it more than ever within the scope of the British Association for the Advancement of Science. 'Man is the ultimate term in the geographical problem,' said Dr. Scott Keltie some years since at the meeting at Toronto. 'Geography is a description of the earth as it is, in relation to man,' said Sir Clements Markham, long President of the Royal Geographical Society. Geography, I venture to think, is becoming more and more a description of the earth as it is and as it will be under the working hand of man. It is becoming intensive rather than extensive. Geographers have to record, and will more and more have to record, how far man has changed and is changing the face of the earth, to try to predict how far he will change it in the coming centuries. The face of the earth has been unveiled by man. Will the earth save her face in the years before us, and, if she saves her face, will it be taken at face value? How far, for instance, will lines of latitude and longitude continue to have any practical meaning?

Man includes the ordinary man, the settler, the agriculturist; man includes, too, the extraordinary—the scientific man, the inventor, the engineer. 'Man,' says a writer on the subject, 'is truly a geographical agency,' and I ask you to take account of this agency for a few minutes. I do so more especially because one of the chief features of the present day is the rise of the South; and the rise of the South—notably of Australia—is the direct result of human agency, on the one hand transforming the surface of the land, on the other eliminating distance. The old name of Australia, as we all know, was New Holland. The name was well chosen in view of later history, for while no two parts of the world could be more unlike one another than the little corner of Europe known as Holland, or the Netherlands, and the great Southern Continent, in the one and in the other man has been pre-eminently a geographical agency.

The writer who used this phrase, 'Man is a geographical agency,' the American writer, Mr. G. P. Marsh, published his book, 'Man and Nature,' in 1864, and a new edition, entitled 'The Earth as Modified by Human Action,' in 1874. He was mainly concerned with the destructiveness of man in the geographical and climatic changes which he has effected. 'Every plant, every animal,' he writes, 'is a geographical agency, man a destructive, vegetables, and in some cases even wild beasts, restorative powers'; and again: 'It is in general true that the intervention of man has hitherto seemed to ensure the final exhaustion, ruin, and desolation of every province of Nature which he has reduced to his dominion.' The more civilised man has become, he tells us, the more he has destroyed. 'Purely untutored humanity interferes comparatively little with the arrangements of Nature, and the destructive agency of man becomes more and more energetic and unsparing as he advances in civilisation.' In short, in his opinion, 'better fifty years of Cathay than a cycle of Europe.'

He took this gloomy view mainly on account of the mischief done by cutting down forests. Man has wrought this destruction not only with his own hand, but through domesticated animals more destructive than wild beasts, sheep, goats, horned cattle, stunting or killing the young shoots of trees. Writing of Tunisia, Mr. Perkins, the late able Principal of Roseworthy College, says: 'In so far as young trees and shrubs are concerned, the passage of a flock of goats will do quite as much damage as a bush fire.' Mr. Marsh seems to have met a fool in the forest, and it was man; and he found him to be more knave than fool, for man has been, in Mr. Marsh's view, the revolutionary Radical confiscating Nature's vested interests. 'Man,' he says, 'has too long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste.' Trees, to his mind, are Conservatives of the best kind. They stand in the way, it is true, but they stop excesses, they moderate the climate, they give shelter against the wind, they store the water, prevent inundations, preserve and enrich the soil. 'The clearing of the woods,' he says, 'has in some cases produced within two or three generations effects as blasting as those generally ascribed to geological convulsions, and has laid waste the face of the earth more hopelessly than if it had been buried by a current of lava or a shower of volcanic sand'; and, once more, where forests have been destroyed, he says, 'The face of the earth is no longer a sponge but a dust-heap.'

The damage done by cutting down trees, and thereby letting loose torrents

which wash away the soil, is or was very marked in the South of France, in Dauphiné, Provence, and the French Alps. With the felling of trees and the pasturing of sheep on the upper edge of the forest—for sheep break the soil and expose the roots—the higher ground has been laid bare. Rainstorms have in consequence swept off the soil, and the floods have devastated the valleys. The mountain-sides have become deserts, and the valleys have been turned into swamps. 'When they destroyed the forest,' wrote the great French geographer, Reclus, about thirty years ago, 'they also destroyed the very ground on which it stood'; and then he continues: 'The devastating action of the streams in the French Alps is a very curious phenomenon in the historical point of view, for it explains why so many of the districts of Syria, Greece, Asia Minor, Africa, and Spain have been forsaken by their inhabitants. The men have disappeared along with the trees; the axe of the woodman, no less than the sword of the conqueror, have put an end to, or transplanted, entire populations.' In the latter part of the South African war Sir William Willcocks, skilled in irrigation in Egypt, and subsequently reclaiming Mesopotamia, was brought to South Africa to report upon the possibilities of irrigation there, and in his report dated November 1901 he wrote as follows: 'Seeing in Basutoland the effect of about thirty years of cultivation and more or less intense habitation convinced me of the fact that another country with steep slopes and thin depth of soil, like Palestine, has been almost completely denuded by hundreds of years of cultivation and intense habits. The Palestine which Joshua conquered and which the children of Israel inhabited was in all probability covered over great part of its area by sufficient earth to provide food for a population a hundred times as dense as that which can be supported to-day.' The Scotch geologist, Hugh Miller, again, attributed the formation of the Scotch mosses to the cutting down of timber by Roman soldiers. 'What had been an overturned forest became in the course of years a deep morass.'

In past times there have been voices raised in favour of the forests, but they have been voices crying in the desert which man has made. Here is one. The old chronicler Holinshed, who lived in the reign of Queen Elizabeth, noted the amount of timber cut down for house building and in order to increase the area for pasturage. 'Every small occasion in my time,' he writes, 'is enough to cut down a great wood'; and in another passage either he himself or one of his collaborators writes that he would wish to live to see four things reformed in England: 'The want of discipline in the Church, the covetous dealing of most of our merchants in the preferment of commodities of other countries and hindrance of their own, the holding of fairs and markets upon the Sunday to be abolished and referred to the Wednesdays, and that every man in whatever part of the champaine soil enjoyeth forty acres of land and upwards after that rate, either by free deed, copyhold or fee farm, might plant one acre of wood or sow the same with oke mast, hazell, beach, and sufficient provision be made that it be cherished and kept.'

Mr. Marsh seems to have thought that the Old World, and especially the countries which formed the old Roman Empire, had been ruined almost past redemption; and for the beneficent action of man on Nature he looked across the seas. 'Australia and New Zealand,' he writes, 'are perhaps the countries from which we have a right to expect the fullest elucidation of these difficult and disputable problems. Here exist greater facilities and stronger motives for the careful study of the topics in question than have ever been found combined in any other theatre of European colonisation.'

His book was first written half a century ago. He was a pessimist evidently, and pessimists exaggerate even more than optimists, for there is nothing more exhilarating and consoling to ourselves than to predict the worst possible consequences from our neighbours' folly. Further, though it may be true that man became more destructive as he became more civilised, it is also true that the destruction has been wrought directly rather by the unscientific than by the scientific man. If we have not grown less destructive since, at any rate we have shown signs of penitence, and science has come to our aid in the work of reparation. Governments and associations have turned their attention to protecting woodland and reafforesting tracts which have been laid bare. The Touring Club of France, for instance, I am told, have taken up the question of the damage done by destruction of trees by men and sheep in Haute Savoie, and they assist

reclamation by guidance and by grants. In England, under the auspices of Birmingham University and under the Presidency of Sir Oliver Lodge, the Midlands Reafforestation Association is planting the pit mounds and ash quarries of the Black Country with trees which will resist smoke and bad air, alders, willows, poplars; carrying out their work, a report says, under a combination of difficulties not to be found in any other country. Artificial lakes and reservoirs again, such as I shall refer to presently, are being made woodland centres. In most civilised countries nowadays living creatures are to some extent protected, tree planting is encouraged by Arbor days, and reserves are formed for forests, for beasts and birds, the survivors of the wild fauna of the earth. Some lands, such as Greece, as I gather from Mr. Perkins' report, are still being denuded of trees, but as a general rule the human conscience is becoming more and more alive to the immorality and the impolicy of wasting the surface of the earth and what lives upon it, and is even beginning to take stock as to whether the minerals beneath the surface are inexhaustible. Therefore I ask you now to consider man as the lord of creation in the nobler sense of the phrase, as transforming geography, but more as a creative than as a destructive agency.

How far has the agency of man altered, how far is it likely to alter, the surface of the earth, the divisions and boundaries assigned by Nature, the climate, and the production of the different parts of the globe; and, further, how far, when not actually transforming Nature, is human agency giving Nature the go-by? It should be borne in mind that science has effected, and is effecting transformation, partly by applying to old processes far more powerful machinery, partly by introducing new processes altogether; and that, as each new force is brought to light, lands and peoples are to a greater or less extent transformed. The world was laid out afresh by coal and steam. A new readjustment is taking place with the development of water power and oil power. Lands with no coal, but with fine water power or access to oil, are asserting themselves. Oil fuel is prolonging continuous voyages and making coaling stations superfluous. But of necessity it is the earth herself who gives the machinery for altering her own surface. The application of the machinery is contributed by the wit of man.

The surface of the earth consists of land and water. How far has human agency converted water into land or land into water, and how far, without actually transforming land into water and water into land, is it for practical human purposes altering the meaning of land and water as the great geographical divisions? A writer on the Fens of South Lincolnshire has told us: 'The Romans, not content with appropriating land all over the world, added to their territory at home by draining lakes and reclaiming marshes." We can instance another great race which, while appropriating land all over the world, has added to it by reclaiming land from water, fresh or salt. The traveller from Great Britain to the most distant of the great British possessions, New Zealand, will find on landing at Wellington a fine street, Lambton Quay, the foreshore of the old beach, seaward of which now rise many of the city's finest buildings on land reclaimed from the sea; and instances of the kind might be indefinitely multiplied. Now the amount of land taken from water by man has been taken more from fresh water than from sea, and, taken in all, the amount is infinitesimal as compared with the total area of land and water; but it has been very considerable in certain small areas of the earth's surface, and from these small areas have come races of men who have profoundly modified the geography and history of the world. This may be illustrated from the Netherlands and from Great Britain.

Motley, at the beginning of 'The Dutch Republic,' writes of the Netherlands: 'A region, outcast of ocean and earth, wrested at last from both domains their richest treasures.' Napoleon was credited with saying that the Netherlands were a deposit of the Rhine, and the rightful property of him who controlled the sources; and an old writer pronounced that Holland was the gift of the ocean and of the rivers Rhine and Meuse, as Egypt is of the river Nile. The crowning vision of Goethe's Faust is that of a free people on a free soil, won from the sea and kept for human habitation by the daily effort of man. Such has been the story of the Netherlands. The Netherlands, as a home for civilised men, were, and are, the result of reclamation, of dykes and polders.

The kingdom has a constantly changing area of between 12,000 and 13,000 square miles. Mr. Marsh, in his book, set down the total amount gained to agriculture at the time he wrote 'by dyking out the sea and by draining shallow bays and lakes' at some 1,370 square miles, which, he says, was one-tenth of the kingdom; at the same time, he estimated that much more had been lost to the sea —something like 2,000 square miles. He writes that there were no important sea dykes before the thirteenth century, and that draining inland lakes did not begin till the fifteenth, when windmills came into use for pumping. In the nineteenth century steam pumps took the place of windmills, science strengthening an already existing process. Between 1815 and 1855, 172 square miles were reclaimed, and this included the Lake of Haarlem, some thirteen miles long by six in breadth, with an area of about seventy-three square miles. This was reclaimed between 1840 and 1853. At the present time, we are told, about forty square miles are being reclaimed annually in Holland; and meanwhile the Dutch Government have in contemplation or in hand a great scheme for draining the Zuyder Zee, which amounts to recovering from the ocean land which was taken by it in historic times at the end of the fourteenth century. The scheme is to be carried out in thirty-three years and is to cost nearly sixteen million pounds. The reclamation is to be effected by an embankment across the mouth of this inland sea over eighteen miles long. The result will be to add 815 square miles of land to the kingdom of the Netherlands, 750 square miles of which will be fertile land, and in addition to create a much-needed freshwater lake with an area of 557 square miles; this lake is to be fed by one of the mouths of the Rhine.

London is partly built on marsh. The part of London where I live, Pimlico, was largely built on piles. A little way north, in the centre of fashion, is Belgrave Square, and here a lady whom I used to know had heard her grandfather say that he had shot snipe. Take the City of London in the strict and narrow sense. The names of Moorfields and Fensbury or Finsbury are familiar to those who know the City. Stow, in his Survey of London, over three hundred years ago, wrote of 'The Moorfield which lieth without the postern called Moorgate. This field of old time was called the Moor. This fen or moor field, stretching from the wall of the city betwixt Bishopsgate and the postern called Cripplegate to Fensbury and to Holywell continued a waste and unprofitable ground a long time.' By 1527, he tells us, it was drained 'into the course of Walbrook, and so into the Thames, and by these degrees was this fen or moor at length made main and hard ground which before, being overgrown with flags, sedges and rushes, served to no use.' It is said that this fen or marsh had come into being since Roman times. The reclamation which has been carried out in the case of London is typical of what has been done in numerous other cases. As man has become more civilised, he has come down from his earlier home in the uplands, has drained the valley swamps, and on the firm land thus created has planted the streets and houses of great cities.

The Romans had a hand in the draining of Romney Marsh in Sussex, and here Nature co-operated with man, just as she has co-operated in the deltas of the great rivers, for the present state of the old Cinque Ports, Rye and Winchelsea, shows how much on this section of the English coast the sea has receded. But the largest reclamation was in East Anglia, where the names of the Fens and the Isle of Ely testify to what the surface once was. 'For some of our fens,' writes Holinshed, 'are well known to be either of ten, twelve, sixteen, twenty or thirty miles in length. . . . Wherein also Elie, the famous isle, standeth, which is seven miles every way, and whereunto there is no access but by three causies.' Arthur Young, in 1799, in his 'General View of the Agriculture of the County of Lincoln,' a copy of which he dedicated to that great friend of Australia, Sir Joseph Banks, who was a Lincolnshire landowner and a keen supporter of reclamation, wrote of the draining which had been carried out in Lincolnshire. 'The quantity of land thus added to the kingdom has been great; fens of water, mud, wild fowl, frogs and agues have been converted to rich pasture and arable worth from 20*s.* to 40*s.* an acre . . . . without going back to very remote periods, there cannot have been less than 150,000 acres drained and improved on an average from 5*s.* an acre to 25*s.*' 150,000 acres is about 234 square miles, but the amount reclaimed by draining in Lincolnshire in the seventeenth, eighteenth and nineteenth centuries seems

to have been well over 500 square miles. The Fenlands as a whole extended into six counties. They were seventy miles in length, from ten to thirty miles broad, and covered an area of from 800 to 1,000 square miles. One estimate I have seen is as high as 1,200 square miles. Mr. Prothero, in his book on 'English Farming, Past and Present,' tells us that they were 'in the seventeenth century a wilderness of bogs, pools and reed shoals—a vast morass from which here and there emerged a few islands of solid earth.' In the seventeenth century a Dutch engineer, Vermuyden, was called in to advise, and the result of draining what was called after the peer who contracted for it the Bedford Level, together with subsequent reclamations, was to convert into ploughland and pasture large tracts which, in the words of an old writer, Dugdale, had been 'a vast and deep fen, affording little benefit to the realm other than fish or fowl, with overmuch harbour to a rude and almost barbarous sort of lazy and beggarly people.' In Lincolnshire there was a district called Holland, and in Norfolk one called Marshland, said to have been drained by, to quote Dugdale again, 'those active and industrious people, the Romans.'

The Dutch and the English, who thus added to their home lands by reclamation, went far and wide through the world, changing its face as they went. The Dutch, where they planted themselves, planted trees also; and when they came to land like their own Netherlands, again they reclaimed and empoldered. The foreshore of British Guiana, with its canals and sea defences, dating from Dutch times, is now the chief sugar-producing area in the British West Indies. If again in Australia man has been a geographical agency, he learnt his trade when he was changing the face of his old home in the British Isles.

Instances of reclaiming land from water might be indefinitely multiplied. We might compare the work done by different nations. In Norway, for instance, Reclus wrote that 'the agriculturists are now reclaiming every year forty square miles of the marshes and fiords.' Miss Semple, who, in the 'Influences of Geographic Environment,' writes that 'between the Elbe and Scheldt' (that is, including with the Netherlands some of North Germany) 'more than 2,000 square miles have been reclaimed from river and sea in the past 300 years,' tells us also that 'the most gigantic dyke system in the world is that of the Hoangho, by which a territory of the size of England is won from the water for cultivation.' Or we might take the different objects which have impelled men here and there to dry up water and bank out sea. Agriculture has not been the only object, nor yet reclaiming for town sites. Thus, in order to work the hematite iron mines at Hodbarrow, in Cumberland, an area of 170 acres was, in the years 1900-04, reclaimed from the sea by a barrier over 1¼ mile long, designed by the great firm of marine engineers, Coode and Matthews, who built the Colombo breakwater. The reclaimed land, owing to the subsidence caused by the workings, is now much below the level of the sea. Here is an instance of reclamation not adding to agricultural or pastoral area, but giving mineral wealth, thereby attracting population and enriching a district.

How far has land been drowned by the agency of man? Again the total area is a negligible quantity, but again, relatively to small areas, it has been appreciable, and the indirect effects have been great. God made the country, man made the town; and the town is trying to unmake or to remake the country. The necessities of town life are responsible for new lakes and rivers. Such are the great reservoirs and aqueducts by which water is being brought to New York from the Catskill Mountains, one of the reservoirs being twelve miles long with a water surface of nearly thirteen square miles. The whole work has been described by a writer in the *Times* as 'hardly second in magnitude and importance to the Panama Canal.' In Great Britain cities in search of a water supply have ordered houses, churches, fields to be drowned, and small lakes to come into existence. Liverpool created Lake Vyrnwy in Montgomeryshire, with a length of nearly five miles and an area of 1,121 acres. Birmingham is the parent of similar lakes in a wild Radnorshire valley near my old home. The water is not carried for anything like the distance from Mundaring to Kalgoorlie, and on a much greater scale than these little lakes in Wales is the reservoir now being formed in New South Wales by the Burrinjuck dam, on the Murrumbidgee River, which, as I read, is, or will be, forty-one miles long, and cover an area of twenty square miles. If I under-

stand right, in this case, by constructing a giant dam over 200 feet high across a gorge through which the river flows, a long narrow lake has been or is being called into existence. A still larger volume of water is gathered by the great Assouan dam, which holds up the Nile at the head of the First Cataract, washing, and at times submerging, the old temples on the Island of Philæ in mid-stream. First completed in 1902, the dam was enlarged and heightened by 1912; and the result of the dam is at the time of high Nile to create a lake of some 65 square miles in area, as well as to fill up the channel of the river for many miles up stream. Illustrations of artificial lakes might be multiplied from irrigation works in India. An official report on the State of Hyderabad, written some years ago, has the following reference to the tanks in the granitic country of that State: 'There are no natural lakes, but from the earliest times advantage has been taken of the undulating character of the country to dam up some low ground or gorge between two hills, above which the drainage of a large area is collected. Such artificial reservoirs are peculiar to the granitic country, and wherever groups of granite hills occur tanks are sure to be found associated with them.' Take again the great ship canals. The Suez Canal runs for 100 miles from sea to sea, though for part of its course it runs through water, not through sand. It is constantly growing in depth and width. Its original depth was $26\frac{1}{4}$ feet; it is now, for nine-tenths of its length, over 36 feet, and the canal is to be further deepened generally to over 39 feet. Its original width at the bottom was 72 feet; it is now, for most of its course, over 147 feet; in other words, the width has been more than doubled. A writer in the *Times* on the wonderful Panama Canal said: 'The locks and the Gatun dam have entailed a far larger displacement of the earth's surface than has ever been attempted by the hand of man in so limited a space.' Outside the locks the depth is 45 feet, and the minimum bottom width 300 feet. The official handbook of the Panama Canal says: 'It is a lake canal as well as a lock canal, its dominating feature being Gatun Lake, a great body of water covering about 164 square miles.' The canal is only fifty miles long from open sea to open sea, from shore line to shore line only forty. But, in making it, man, the geographical agency, has blocked the waters of a river, the Chagres river, by building up a ridge which connects the two lines of hills between which the river flows, this ridge being a dam $1\frac{1}{2}$ miles long, nearly half a mile wide at its base, and rising to 105 feet above sea-level, with the result that a lake has come into existence which is three-quarters of the size of the Lake of Geneva, and extends beyond the limits of the Canal zone. When all the sluices are open, a greater volume of water passes through them than comes over the Falls of Niagara.

Mr. Marsh, in his book, referred to far more colossal schemes for turning land into water, such as flooding the African Sahara or cutting a canal from the Mediterranean to the Jordan and thus submerging the basin of the Dead Sea, which is below the level of the ocean. The effect of the latter scheme, he estimated, would be to add from 2,000 to 3,000 square miles to the fluid surface of Syria. All that can be said is that the wild-cat schemes of one century often become the domesticated possibilities of the next and the accomplished facts of the third; that the more discovery of new lands passes out of sight the more men's energies and imagination will be concentrated upon developing and altering what is in their keeping; and that, judging from the past, no unscientific man can safely set any limit whatever to the future achievements of science.

But now, given that the proportion of land to water and water to land has not been, and assuming that it will not be, appreciably altered, has water, for practical purposes, encroached on land, or land on water? In many cases water transport has encroached on land transport. The great isthmus canals are an obvious instance; so are the great Canadian canals. The tonnage passing through the locks of the Sault St. Marie is greater than that which is carried through the Suez Canal. Waterways are made where there was dry land, and more often existing inland waterways are converted into sea-going ways. Manchester has become a seaport through its Ship Canal. The Clyde, in Mr. Vernon Harcourt's words, written in 1895, has been 'converted from an insignificant stream into a deep navigable river capable of giving access to ocean-going vessels of large draught up to Glasgow.' In 1758 the Clyde at low water

at Glasgow was only 15 inches deep, and till 1818 no seagoing vessels came up to Glasgow. In 1895 the depth at low water was from 17 to 20 feet, and steamers with a maximum draught of $25\frac{1}{2}$ feet could go up to Glasgow. This was the result of dredging, deepening and widening the river, and increasing the tidal flow. The record of the Tyne has been similar. The effect of dredging the Tyne was that in 1895—I quote Mr. Harcourt again—'Between Shields and Newcastle, where formerly steamers of only 3 to 4 feet draught used to ground for hours, there is now a depth of 20 feet throughout at the lowest tides.' It is because engineers have artificially improved Nature's work on the Clyde and the Tyne that these rivers have become homes of shipbuilding for the whole world. Building training walls on the Seine placed Rouen, seventy-eight miles up the river, high among the seaports of France. The Elbe and the Rhine, the giant rivers Mississippi and St. Lawrence, and many other rivers, have, as we all know, been wonderfully transformed by the hand of the engineer.

But land in turn, in this matter of transport, has encroached upon sea. In old days, when roads were few and bad, when there were no railways, and when ships were small, it was all-important to bring goods by water at all parts as far inland as possible. In England there were numerous flourishing little ports in all the estuaries and up the rivers, which, under modern conditions, have decayed. No one now thinks of Canterbury and Winchester in connection with seaborne traffic; but Mr. Belloc, in 'The Old Road,' a description of the historical Pilgrims' Way from Winchester to Canterbury, points out how these two old-world cathedral cities took their origin and derived their importance from the fact that each of them, Canterbury in particular, was within easy reach of the coast, where a crossing from France would be made; each on a river—in the case of Canterbury on the Stour just above the end of the tideway. In the days when the Island of Thanet was really an island, separated from the rest of Kent by an arm of the sea, and when the present insignificant river Stour was, in the words of the historian J. R. Green, 'a wide and navigable estuary,' Canterbury was a focus to which the merchandise of six Kentish seaports was brought, to pass on inland; it was in effect practically a seaport. Now merchandise, except purely local traffic, comes to a few large ports only, and is carried direct by rail to great distant inland centres. Reclus wrote that bays are constantly losing in comparative importance as the inland ways of rapid communication increase; that, in all countries intersected with railways, indentations in the coast-line have become rather an obstacle than an advantage; and that maritime commerce tends more and more to take for its starting-place ports situated at the end of a peninsula. He argues, in short, that traffic goes on land as far out to sea as possible instead of being brought by water as far inland as possible. He clearly overstated the case, but my contention is that, for human purposes, the coast-line, though the same on the map, has practically been altered by human agency. By the aid of science ports have been brought to men as much as men to ports. We see before our eyes the process going on of bridging India to Ceylon so as to carry goods and passengers as far by land as possible, and in Ceylon we see the great natural harbour of Trincomalee practically deserted and a wonderful artificial harbour created at the centre of population, Colombo.

But let us carry the argument a little further. Great Britain is an island. Unless there is some great convulsion of Nature, to all time the Straits of Dover will separate it from the continent of Europe. Yet we have at this moment a renewal of the scheme for a Channel tunnel, and at this moment men are flying from England to France and France to England. Suppose the Channel tunnel to be made; suppose flying to be improved—and it is improving every day—what will become of the island? What will become of the sea? They will be there and will be shown on the map, but to all human intents and purposes the geography will be changed. The sea will no longer be a barrier, it will no longer be the only high-road from England to France. There will be going to and fro on or in dry land, and going to and fro neither on land nor on sea. Suppose this science of aviation to make great strides, and heavy loads to be carried in the air, what will become of the ports, and what will become of sea-going peoples? The ports will be there, appearing as now on the map, but Birmingham goods will be shipped at Birmingham for foreign parts, and

Lithgow will export mineral direct, saying good-bye to the Blue Mountains and even to Sydney Harbour.

Now, in saying this I may well be told by my scientific colleagues that it is all very well as a pretty piece of fooling, but that it is not business. I say it as an unscientific man with a profound belief in the unbounded possibilities of science. How long is it since it was an axiom that, as a lump of iron sinks in water, a ship made of iron could not possibly float? Is it fatuous to contemplate that the conquest of the air, which is now beginning, will make it a highway for commercial purposes? We have aeroplanes already which settle on the water and rise again; we are following on the track of the gulls which we wonder at in the limitless waste of ocean. A century and a half ago the great Edmund Burke ridiculed the idea of representatives of the old North American colonies sitting in the Imperial Parliament; he spoke of any such scheme as fighting with Nature and conquering the order of Providence; he took the distance, the time which would be involved—six weeks from the present United States to London. If anyone had told him that what is happening now through the applied forces of science might happen, he would have called his informant a madman. Men think in years, or at most in lifetimes; they ought sometimes to think in centuries. I believe in Reclus's words, 'All man has hitherto done is a trifle in comparison with what he will be able to effect in future.' Science is like a woman. She says No again and again, but she means Yes in the end.

In dealing with land and water I have touched upon natural divisions and natural boundaries, which are one of the provinces of geography. Flying gives the go-by to all natural divisions and boundaries, even the sea; but let us come down to the earth. Isthmuses are natural divisions between seas; the ship canals cut them and link the seas—the canal through the Isthmus of Corinth, the canal which cuts the Isthmus of Perekop between the Crimea and the mainland of Russia, the Baltic Canal, the Suez Canal, the Panama Canal. The Suez Canal, it will be noted, though not such a wonderful feat as the Panama Canal, is more important from a geographical point of view, in that an open cut has been made from sea to sea without necessity for locks, which surmount the land barrier but more or less leave it standing. Inland, what are natural divisions? Mountains, forests, deserts, and, to some extent, rivers. Take mountains. 'High, massive mountain systems,' writes Miss Semple, 'present the most effective barriers which man meets on the land surface of the earth.' But are the Rocky Mountains, for instance, boundaries, dividing-lines, to anything like the extent that they were now that railways go through and over them, carrying hundreds of human beings back and fore day by day? On what terms did British Columbia join the Dominion of Canada? That the natural barrier between them should be pierced by the railway. Take the Alps. The canton Ticino, running down to Lake Maggiore, is politically in Switzerland; it is wholly on the southern side of the Alps. Is not the position entirely changed by the St. Gothard tunnel, running from Swiss territory into Swiss territory on either side of the mountains?

If, in the Bible language, it requires faith to remove mountains, it is not wholly so with other natural boundaries. Forests were, in old days, very real natural dividing-lines. They were so in England, as in our own day they have been in Central Africa. Between forty and fifty years ago, in his 'Historical Maps of England,' Professor C. H. Pearson, whose name is well known and honoured in Australia, laid down that England was settled from east and west, because over against Gaul were heavy woods, greater barriers than the sea. Kent was cut off from Central England by the Andred Weald, said to have been, in King Alfred's time, 120 miles long and 30 broad. Here are Professor Pearson's words: 'The axe of the woodman clearing away the forests, the labour of nameless generations reclaiming the fringes of the fens or making their islands habitable, have gradually transformed England into one country, inhabited by one people. But the early influences of the woods and fens are to isolate and divide.' Thus the cutting down of trees is sometimes a good, not an evil, and there are some natural boundaries which man can wholly obliterate.

Can the same be said of deserts? They can certainly be pierced, like isthmuses and like mountains. The Australian desert is a natural division

between Western and South Australia. The desert will be there for many a long day after the transcontinental railway has been finished, but will it be, in anything like the same sense as before, a barrier placed by Nature and respected by man? Nor do railways end with simply giving continuous communication, except when they are in tunnels. As we all know, if population is available, they bring in their train development of the land through which they pass. Are these deserts of the earth always going to remain, in Shakespeare's words, 'deserts idle'? Is man going to obliterate them? In the days to come, will the desert rejoice and blossom as the rose? What will dry farming and what will afforestation have to say? In the evidence taken in Australia by the Dominions Royal Commission, the Commissioner for Irrigation in New South Wales tells us that 'the dry farming areas are carried out westward into what are regarded as arid lands every year,' and that, in his opinion, 'we are merely on the fringe of dry farming' in Australia. A book has lately been published entitled 'The Conquest of the Desert.' The writer, Dr. Macdonald, deals with the Kalahari Desert in South Africa, which he knows well, and for the conquest of the desert he lays down that three things are essential—population, conservation, and afforestation. He points out in words which might have been embodied in Mr. Marsh's book, how the desert zone has advanced through the reckless cutting of trees, and how it can be flung back again by tree barriers to the sand dunes. By conservation he means the system of dry farming so successful in the United States of America, which preserves the moisture in the soil and makes the desert produce fine crops of durum wheat without a drop of rain falling upon it from seedtime to harvest, and he addresses his book 'to the million settlers of to-morrow upon the dry and desert lands of South Africa.' If the settlers come, he holds that the agency of man, tree-planting, ploughing and harrowing the soil, will drive back and kill out the desert. The effect of tree-planting in arresting the sand dunes and reclaiming desert has been very marked in the Landes of Gascony. Here, I gather from Mr. Perkins' report, are some 3600 square miles of sandy waste, more than half of which had, as far back as 1882, been converted into forest land, planted mainly with maritime pines.

What, again, will irrigation have to say to the deserts? Irrigation, whether from underground or from overground waters, has already changed the face of the earth, and as the years go on, as knowledge grows and wisdom, must inevitably change it more and more. I read of underground waters in the Kalahari. I read of them too in the Libyan Desert. In the 'Geographical Journal' for 1902 it is stated that at that date nearly 22,000 square miles in the Algerian Sahara had been reclaimed with water from artesian wells. What artesian and sub-artesian water has done for Australia you all know. If it is not so much available for agricultural purposes, it has enabled flocks and herds to live and thrive in what would be otherwise arid areas. Professor Gregory, Mr. Gibbons Cox, and others have written on this subject with expert knowledge; evidence has been collected and published by the Dominions Royal Commission, but I must leave to more learned and more controversial men than I am to discuss whether the supplies are plutonic or meteoric, and how far in this matter you are living on your capital.

If we turn to irrigation from overground waters, I hesitate to take illustrations from Australia, because my theme is the blotting out of the desert; and most of the Australian lands which are being irrigated from rivers, and made scenes of closer settlement, would be libelled if classed as desert. Mr. Elwood Mead told the Royal Commission that the State irrigation works in Victoria, already completed or in process of construction, can irrigate over 600 square miles, and that, if the whole water supply of the State were utilised, more like 6000 square miles might be irrigated. The Burrinjuck scheme in New South Wales will irrigate in the first instance not far short of 500 square miles, but may eventually be made available for six times that area. If we turn to irrigation works in India, it appears from the second edition of Mr. Buckley's work on the subject, published in 1905, that one canal system alone, that of the Chenab in the Punjab, had, to quote his words, turned 'some two million acres of wilderness (over 3000 square miles) into sheets of luxuriant crops.' 'Before the construction of the canal,' he writes, 'it was almost entirely waste, with an extremely small population, which was mostly nomad. Some portion of the country was wooded with jungle trees, some was covered with small scrub

camel thorn, and large tracts were absolutely bare, producing only on occasions a brilliant mirage of unbounded sheets of fictitious water.' The Chenab irrigation works have provided for more than a million of human beings; and, taking the whole of India, the Irrigation Commission of 1901-3 estimated that the amount of irrigated land at that date was 68,750 square miles; in other words, a considerably larger area than England and Wales. Sir William Willcocks has been reclaiming the delta of the Euphrates and Tigris. The area is given as nearly 19,000 square miles, and it is described as about two-thirds desert and one-third freshwater swamp. Over 4000 square miles of the Gezireh Plain, between the Blue and the White Nile, are about to be reclaimed, mainly for cotton cultivation, by constructing a dam on the Blue Nile at Sennaar and cutting a canal 100 miles long which, if I understand right, will join the White Nile, thirty miles south of Khartoum.

With the advance of science, with the growing pressure of population on the surface of the earth, forcing on reclamation as a necessity for life, is it too much to contemplate that human agency in the coming time will largely obliterate the deserts which now appear on our maps? It is for the young peoples of the British Empire to take a lead in—to quote a phrase from Lord Durham's great report—'the war with the wilderness,' and the great feat of carrying water for 350 miles to Kalgoorlie, in the very heart of the wilderness, shows that Australians are second to none in the ranks of this war.

It is a commonplace that rivers do not make good boundaries because they are easy to cross by boat or bridge. Pascal says of them that they are 'des chemins qui marchent' (roads that move), and we have seen how these roads have been and are being improved by man. 'Rivers unite,' says Miss Semple; and again, 'Rivers may serve as political lines of demarcation, and therefore fix political frontiers, but they can never take the place of natural boundaries.' All the same, in old times at any rate, rivers were very appreciable dividing-lines, and when you get back to something like barbarism, that is to say in time of war, it is realised how powerful a barrier is a river. Taking, then, rivers as in some sort natural boundaries, or treating them only as political boundaries, the point which I wish to emphasise is that they are becoming boundaries which, with modern scientific appliances, may be shifted at the will of man. In the days to come the diversion of rivers may become the diversion of a new race of despotic rulers with infinitely greater power to carry out their will or their whim than the Pharaohs possessed when they built the Pyramids. You in Australia know how thorny a question is that of the control of the Murray and its tributaries. There are Waterways Conventions between Canada and the United States. Security for the head-waters of the Nile was, and is, a prime necessity for the Sudan and Egypt. The Euphrates is being turned from one channel into another. What infinite possibilities of political and geographical complications does man's growing control over the flow of rivers present!

Thus I have given you four kinds of barriers or divisions set by Nature upon the face of the earth—mountains, forests, deserts, rivers. The first, the mountains, man cannot remove, but he can and he does go through them to save the trouble and difficulty of going over them. The second, the forests, he has largely cleared away altogether. The third, the deserts, he is beginning to treat like the forests. The fourth, the rivers, he is beginning to shift when it suits his purpose and to regulate their flow at will.

I turn to climates. Climates are hot or cold, wet or dry, healthy or unhealthy. Here our old friends the trees have much to say. Climates beyond dispute become at once hotter and colder when trees have been cut down and the face of the earth has been laid bare; they become drier or moister according as trees are destroyed or trees are planted and hold the moisture; the cutting and planting of timber affects either one way or the other the health of a district. The tilling of the soil modifies the climate. This has been the case, according to general opinion, in the North-West of Canada, though I have not been able to secure any official statistics on the subject. In winter time broken or ploughed land does not hold the snow and ice to the same extent as the unbroken surface of the prairie; on the other hand, it is more retentive at once of moisture and of the rays of the sun. The result is that the wheat zone has moved further north, and that the intervention of man has, at any rate for agricultural purposes, made the climate of the great Canadian North-West

perceptibly more favourable than it was. In Lord Strathcona's view, there was some change even before the settlers came in, as soon as the rails and telegraph lines of the Canadian Pacific Railway were laid. He told me that in carrying the line across a desert belt it was found that, within measurable distance of the rail and the telegraph line, there was a distinct increase of dew and moisture. I must leave it to men of science to say whether this was the result of some electrical or other force, or whether what was observed was due simply to a wet cycle coinciding with the laying of the rails and the erection of the wires. I am told that it is probably a coincidence of this kind which accounts for the fact that in the neighbourhood of the Assouan dam there is at present a small annual rainfall, whereas in past years the locality was rainless. Reference has already been made to the effect of cultivation in the Kalahari Desert in increasing the storage of moisture in the soil. But it is when we come to the division between healthy and unhealthy climates that the effect of science upon climate is most clearly seen. The great researches of Ross, Manson, Bruce, and many other men of science, British and foreign alike, who have traced malaria and yellow fever back to the mosquito, and assured the prevention and gradual extirpation of tropical diseases, bid fair to revolutionise climatic control. Note, however, that in our penitent desire to preserve the wild fauna of the earth we are also establishing preserves for mosquitos, trypanosomes and the tsetse fly.

Nowhere have the triumphs of medical science been more conspicuous than where engineers have performed their greatest feats. De Lesseps decided that Ismailia should be the headquarters of the Suez Canal, but the prevalence of malaria made it necessary to transfer the headquarters to Port Said. In 1886 there were 2300 cases of malaria at Ismailia; in 1900 almost exactly the same number. In 1901 Sir Ronald Ross was called in to advise; in 1906 there were no fresh cases, and malaria has been stamped out. Lesseps' attempt to construct the Panama Canal was defeated largely, if not mainly, by the frightful death-rate among the labourers; 50,000 lives are said to have been lost, the result of malaria and yellow fever. When the Americans took up the enterprise they started with sending in doctors and sanitary experts, and the result of splendid medical skill and sanitary administration was that malaria and yellow fever were practically killed out. The Panama Canal is a glorious creation of medical as well as of engineering science, and this change of climate has been mainly due to reclamation of pools and swamps, and to cutting down bush, for even the virtuous trees, under some conditions, conduce to malaria. Man is a geographical agency, and in no respect more than in the effect of his handiwork on climate, for climate determines products, human and others. Science is deciding that animal pests shall be extirpated in the tropics, and that there shall be no climates which shall be barred to white men on the ground of danger of infection from tropical diseases.

If we turn to products, it is almost superfluous to give illustrations of the changes wrought by man. As the incoming white man has in many places supplanted the coloured aboriginal, so the plants and the living creatures brought in by the white man have in many cases, as you know well, ousted the flora and fauna of the soil. Here is one well-known illustration of the immigration of plants. Charles Darwin, on the voyage of the *Beagle*, visited the island of St. Helena in the year 1836. He wrote 'that the number of plants now found on the island is 746, and that out of these fifty-two alone are indigenous species.' The immigrants, he said, had been imported mainly from England, but some from Australia, and, he continued, 'the many imported species must have destroyed some of the native kinds, and it is only on the highest and steepest ridges that the indigenous flora is now predominant.'

Set yourselves to write a geography of Australia as Australia was when first made known to Europe, and compare it with a geography now. Suppose Australia to have been fully discovered when Europeans first reached it, but consider the surface then and the surface now, and the living things upon the surface then and now. Will not man be found to have been a geographical agency? How much waste land, how many fringes of desert have been reclaimed? The wilderness has become pasture land, the pasture land is being converted into arable. The Blue Mountains, which barred the way to the interior, are now a health resort. Let us see what Sir Joseph Banks wrote after his visit to Australia on Captain Cook's first voyage in 1770. He has a

chapter headed 'Some Account of that part of New Holland now called New South Wales.' New Holland he thought 'in every respect the most barren country I have seen'; 'the fertile soil bears no kind of proportion to that which seems by nature doomed to everlasting barrenness.' 'In the whole length of coast which we sailed along there was a very unusual sameness to be observed in the face of the country. Barren it may justly be called, and in a very high degree, so far, at least, as we saw.' It is true that he only saw the land by the sea, but it was the richer eastern side of Australia, the outer edge of New South Wales and Queensland. What animals did he find in Australia? He 'saw an animal as large as a greyhound, of a mouse colour, and very swift.' 'He was not only like a greyhound in size and running, but had a tail as long as any greyhound's. What to liken him to I could not tell.' Banks had a greyhound with him, which chased this animal. 'We observed, much to our surprise, that, instead of going upon all fours, this animal went only on two legs, making vast bounds.' He found out that the natives called it kangooroo, and it was 'as large as a middling lamb.' He found 'this immense tract of land,' which he said was considerably larger than all Europe, 'thinly inhabited, even to admiration, at least that part of it that we saw.' He noted the Indians, as he called them, whom he thought 'a very pusillanimous people.' They 'seemed to have no idea of traffic'; they had 'a wooden weapon made like a short scimitar.' Suppose a new Sir Joseph Banks came down from the planet Mars to visit Australia at this moment, what account would he give of it in a geographical handbook for the children of Mars? He would modify the views about barrenness, if he saw the cornfields and flocks and herds; if he visited Adelaide, he would change his opinion as to scanty population, though not so, perhaps, if he went to the back blocks. He would record that the population was almost entirely white, apparently akin to a certain race in the North Sea, from which, by tradition, they had come; that their worst enemies could not call them pusillanimous; that they had some ideas of traffic, and used other weapons than a wooden scimitar; and he would probably give the first place in animal life not to the animal like a greyhound on two legs, but to the middling lamb, or perhaps to the ubiquitous rabbit. Australia is the same island continent that it always was; there are the same indentations of coast, the same mountains and rivers, but the face of the land is different. In past years there was no town, and the country was wilderness; on the surface of the wilderness many of the living things were different; and from under the earth has come water and mineral, the existence of which was not suspected. A century hence it will be different again, and I want to see sets of maps illustrating more clearly than is now the case the changes which successive generations of men have made and are making in the face of Australia and of the whole earth.

More than half a century ago Buckle, in his 'History of Civilisation,' wrote: 'Formerly the richest countries were those in which Nature was most bountiful; now the richest countries are those in which man is most active. For in our age of the world, if Nature is parsimonious we know how to compensate her deficiencies. If a river is difficult to navigate, or a country difficult to traverse, an engineer can correct the error and remedy the evil. If we have no rivers we make canals; if we have no natural harbours we make artificial ones.' These words have a double force at the present day and in the present surroundings, for nowhere has man been more active as a geographical agency than in Australia; and not inside Australia only, but also in regard to the relations of Australia to the outside world.

An island continent Australia is still, and always will be, on the maps. It always will be the same number of miles distant from other lands; but will these maps represent practical everyday facts? What do miles mean when it takes a perpetually diminishing time to cover them? Is it not truer to facts to measure distances, as do Swiss guides, in Stunden (hours)? What, once more, will an island continent mean if the sea is to be overlooked and overflown? The tendency is for the world to become one; and we know perfectly well that, as far as distance is concerned, for practical purposes the geographical position of Australia has changed through the agency of scientific man. If you come to think of it, what geography has been more concerned with than anything else, directly or indirectly, is distance. It is

the knowledge of other places not at our actual door that we teach in geography, how to get there, what to find when we get there, and so forth. The greatest revolution that is being worked in human life is the elimination of distance, and this elimination is going on apace. It is entering into every phase of public and private life, and is changing it more and more. The most difficult and dangerous of all Imperial problems at this moment is the colour problem, and this has been entirely created by human agency, scientific agency, bringing the lands of the coloured and the white men closer together. Year after year, because distance is being diminished, coming and going of men and of products is multiplying; steadily and surely the world is becoming one continent. This is what I want geographers to note and the peoples to learn. Geographers have recorded what the world is according to Nature. I want them to note and teach others to note how under an all-wise Providence it is being subdued, replenished, recast, and contracted by man.

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *Australian Rainfall. By* H. A. HUNT, *Commonwealth Meteorologist.*

The main factors to be considered in relation to the controlling causes of rainfall in Australia are the south-east and westerly trade winds, the monsoonal and southern depressions, cyclones from the north-east and north-west tropics, locally formed cyclones, and the anticyclones, in conjunction with the modifying effects on these various atmospheric movements of the physical features of the different parts of the country.

Around the central dry area of Australia the isohyets describe somewhat concentric curves, the modifications being mostly due to variations in elevation. Thus, the Darling Ranges to a great degree account for the rainfall of the south-west corner of the continent. The Flinders Range (South Australia) and Australian Alps in the south-east have a heavier rainfall than the surrounding tracts owing to their cooling effect on the air-currents. Along the eastern elevated margin of the Commonwealth the ridges between large river-valleys also account for an enhanced precipitation. Examples of the latter type are the Peak Range and Darling Downs in Queensland, where the eastern ranges of the northern parts of that State obstruct the south-east trade winds and cause our heaviest rainfall. In Western Tasmania there is an excessive rainfall for similar reasons, though there the westerly trades are the moisture-laden winds.

During the hotter months, November to April inclusive, the northern parts of Australia are wet and the southern dry, and in the colder months, May to October inclusive, the southern parts are wet and the northern dry, while over the eastern areas of the continent the rainfall is distributed fairly generally throughout the year.

The southern portions of the continent, where the precipitations are controlled by the 'stormy westerlies,' southern cyclones and V-shaped depressions, enjoy very consistent annual totals, but north of the tropics, and in fact in all parts of the continent subject to monsoon rains, the departures from the normal are occasionally very great.

When the monsoonal disturbances are in evidence, the effect of the rainfall on the country generally and the economic results for the succeeding season are very pronounced. The interior of the continent becomes transformed. The plains, which ordinarily have an intensifying effect on the heat winds of the summer, are deluged with rain, and respond immediately with a luxurious growth of grass and herbage. The air is then both tempered in heat and loses its dryness for considerable periods.

The monsoon region comprises the whole of Australia north of the Tropic of Capricorn, together with Southern Queensland and the north of New South Wales. The heaviest rains are in January and February. They are directly

due to the indraught caused by the heating of the centre of the continent. This leads to the formation of a low pressure in Northern Australia, and the ascending winds are cooled and deposit their water-vapour in heavy rainstorms and thunder showers.

Tropical depressions when well developed are productive of good inland rains, and are evidently caused by southward flows of the atmosphere of wide extent and considerable depth. The 'Antarctic' disturbances are, however, the more frequent in winter. The heaviest totals from this last-named source are precipitated on the west coast of Tasmania. Thus at Mount Lyell the total for one year exceeded 140 inches, and even the average is 116·05 inches. When an 'Antarctic' is supplemented by a 'trough' extending well into the northern interior, it brings much rain to the inland areas of South Australia, Victoria, New South Wales, and even Queensland.

Anticyclonic rains occur at all times of the year, but more markedly from March to September. They benefit particularly the southern area of the continent, and are responsible for many of the heaviest rainfalls and floods on the coastal districts of New South Wales.

Flood rains occur at infrequent intervals over various portions of the Commonwealth, principally in Queensland, the south-eastern parts of the continent, and the northern regions of West Australia.

Typical instances of floods in South-eastern Australia are (1) the flood which occurred in January 1910 in the Upper Darling tributaries, consequent on abnormally heavy rains on the north-western plains and slopes of New South Wales, as well as on the Darling Downs of Queensland.

These exceptionally heavy, continuous rains were caused by the joint action of an anticyclonic area over the southern regions and a monsoonal depression operating in the northern half of the continent. A monsoonal tongue developed and extended southwards over Queensland and New South Wales, while at the same time the energy of the high pressure in the south increased. In five days large areas in the two States had from 5 inches to 19 inches of rain. The enormous amount of water which fell over approximately 86,000 square miles of country may be roughly estimated at thirty-one billion, six hundred and eighty-seven million (31,687,000,000) tons, or seven thousand one hundred billion (7,100,000,000,000) gallons.

(2) A similar development occurred in March of the present year, when a monsoonal tongue extending southwards across the continent against an intensified anticyclone in the south was accompanied by severe thunderstorms and torrential rains. Some of the heaviest individual falls were in New South Wales; *e.g.*, Taralga on the Central Tablelands 10·74 inches, Sydney 8·49 inches, Parramatta 16·91 inches, and Beecraft 18·84 inches in the metropolitan area, and Wollongong 25·34 inches, on the south coast. The barometer readings at Sydney ranged from 30·13 inches to 29·97 inches during the five days the storms were in progress, while the anticyclone to the south gradually gave way simultaneously, the centre (30·4 inches) moving slowly over the southern parts of Victoria and Tasmania eastwards to the South Pacific Ocean.

The wettest known place in Australia is Innisfail, on the north east coast of Queensland, where the average rainfall for twenty-one years is no less than 145 inches, the maximum yearly total being 211·24 inches, and the minimum 69·87 inches.

The driest region so far furnished with rain gauges lies east and north-east from Lake Eyre, where less than 5 inches is the average annual rainfall, and where a total of 10 inches is rarely recorded during the twelve months. This minimum rainfall is coincident with the lowest elevation, Lake Eyre being actually below sea-level 39 feet.

The inland districts of Western Australia have until recent years been regarded as the driest part of the Commonwealth, but authentic observations taken during the past decade at settled districts in the east of that State show that the annual average is from 10 to 12 inches.

In comparing the rainfall of the chief cities of the rest of the world [1] with

[1] Amsterdam, Athens, Berlin, Berne, Bombay, Brussels, Budapest, Buenos Ayres, Calcutta, Cape Town, Chicago, Christiania, Colombo, Constantinople, Copenhagen, Dublin, Edinburgh, Genoa, Hong Kong, Johannesburg, Lisbon,

those of Australia, it is found that Bombay, Calcutta, Colombo, Singapore, and Hong Kong are the only cities whose rainfall exceeds that of Sydney and Brisbane. Perth has a greater annual rainfall than New York, and more than that of twenty-eight of the forty-two cities used in the comparison. Hobart nearly equals London, which Melbourne exceeds by an inch, while eleven of the forty-two places considered have less rain than Hobart.

The distribution of average annual rainfall over the Commonwealth and the United Kingdom in *thousands* of square miles is as follows :—

	Australia	British Isles
Under 10 in.	1,045	nil
10 in. to 15 in.	652	nil
15 in. to 20 in.	416	nil
20 in. to 30 in.	503	24
30 in. to 40 in.	199	42
Over 40 in.	160	55

The average area under wheat in the United Kingdom during the years 1910, 1911, and 1912 was 1,926,040 acres, and the average yield 59,436,392 bushels; while in the Commonwealth for the same period the area under wheat was 7,379,980 acres, and the average yield 86,243,133 bushels, a difference in the total yield in favour of Australia of 26,806,741 bushels. In Australia wheat-growing under ordinary conditions is generally considered a safe and payable proposition when 10 inches of rain and over falls from the month of April to that of October inclusive. There are in all 484,330 square miles of country with 10 inches of rainfall and over during the wheat-growing period. The output of wheat has been steadily increasing from year to year, and there are vast possibilities of future development in this direction.

The climatic history and prosperity of the last ten years or so contradict emphatically the preconceived notion that Australia is the particular drought-stricken and precarious area of the earth's surface. These misconceptions of the true character of the country have been held in the developmental stages, to a greater or less extent, in the early histories in the majority of all lands and in the colonisation of newly discovered territories; *e.g.*, see history of colonisation of U.S. America and early Egyptian history. The truth of the matter about Australia's rainfall is that (1) it is generally ample for pastoral and agricultural industries over two-thirds of its area; (2) that different regions have distinct seasonal dry and wet periods. These must be more fully recognised and industrial operations adapted accordingly; (3) it is subject in part, but never in the whole, to prolonged periods when the rainfall is short of the seasonal average. Australia is not peculiar in this respect. It follows, therefore, that as the so far undeveloped country becomes populated and put to profitable use, the general wealth of the community as a whole will steadily increase.

A model representing the relative rainfall over Australia has been constructed at the Commonwealth Weather Bureau on a horizontal scale of 133 miles to 1 inch and a vertical scale of 10 inches to 1 centimetre.

It shows at a glance how the annual rainfall is distributed, from the small precipitation over the far interior to the fringe of high rainfall around the greater portion of the coast-line, culminating on the eastern side in a great peak indicating the annual precipitation over the Harvey Creek and Innisfail district, resulting from the prevailing south-east trade winds carrying the moisture against the mountain ranges just inside the coast.

The fringe of relatively high rainfall along the eastern and south-eastern coasts of the continent as the result of the elevated contours near the coast in those regions is also striking.

The effect of the monsoonal rains over Northern Australia is very apparent from the model, which shows the gradual increase of rainfall from under 10 inches in the interior to over 60 inches on the north coast.

The manner in which the prevailing westerly trade winds carry moisture

London, Madras, Madrid, Marseilles, Moscow, Naples, New York, Ottawa, Paris, Pekin, Quebec, Rome, San Francisco, Shanghai, Singapore, Stockholm, Petrograd, Tokyo, Vienna, Vladivostock, and Washington.

along the southern portion of the Commonwealth is clearly marked by the elevations indicating the good rains received over the south-west corner of Australia, and, further eastward, how the ranges east of Adelaide cause good rainfall there and prevent the rain from that direction reaching the inland parts of Victoria.

In Tasmania also is seen the effect of the frequency of the moist westerly winds, causing high rainfall along the mountain ranges of the west coast, with resulting comparative dryness in the eastern parts of that State.

It may be of interest to note in closing that there exists apparently an oscillatory movement of the seasonal rains throughout Australia about a centre in the vicinity of Forbes, in New South Wales. It is perhaps a natural coincidence that this apparent centre of oscillation is approximately the centre of gravity of the Commonwealth's population, and is not far from the Federal capital site.

This peculiar oscillatory character of the monthly march of rainfall suggested the construction of a 'Rain Clock.' In the centre of a piece of cardboard a map of Australia is cut out with a die. At the back of this another piece of cardboard, indicating the rain area, is manipulated on a swivel. By moving the second piece of cardboard backwards and forwards with an amplitude of oscillation of one-fifth of a circle, the land area of the continent affected by dry or wet conditions at any time of the year is approximately indicated.

The immediate lessons to be learned from a study of the 'Clock' are that the seasonal rains are more regular than was generally believed, and that the alternating dry and wet seasons are definitely defined. That being so, when in obedience to physical law there is an absence of rain during the normally dry period in any part of Australia, such dryness should not be regarded as drought, and an evil, but rather as Nature's wise provision for resting the soil.

2. *The 'Mallee' Country of North-Western Victoria.* *By* A. S. Kenyon, *C.E.*

The term 'Mallee,' applied to the scrubby forms of Eucalypt characteristic of the area to be described, is of aboriginal origin.

The Mallee country embraces over 11,000,000 acres and includes the greater part of the north-western portion of the State, over one-fifth of its total area. It is sharply differentiated from other districts by its soils, plants, and general surface configuration.

Surface Formation.—The prevailing feature is the regular occurrence of sand-ridges—of no great height, generally less than 30 feet. They are more or less parallel, running from W.S.W. to E.N.E. With an increase in their height, the soil becomes noticeably poorer; at times they are over 100 feet above the surrounding surface, when the parallelism is almost completely masked and they form a jumble of sand-hills, locally known as 'desert.' More or less extensive expanses of level land with low irregular undulating rises are termed 'broken' country.

Soil.—The soil varies from rich red clayey loams in the 'broken' country to pure white sand in the 'sandhills,' and, except in the latter class, is all suitable for agriculture. Limestone nodules occur almost everywhere, in places becoming almost massive; outcrops of tertiary agglomerated ferruginous sandstone are plentiful. Salt lakes, generally in the vicinity of the more extensive limestone beds, accompanied with 'copi' or gypsum earth deposits, are numerous. These have rarely any inflow of water, and their saltness in every case may be put down to upward filtration. Swamps and terminal lakes without any outflow are, however, generally fresh. The 'broken' country occupies about 20 per cent., the sand-ridges cover 50 per cent., while the sand-hills account for less than 30 per cent.

Plants.—The sand-ridge country is densely covered with *E. Dumosa* and its varieties. Broom-bush (*Bæckea*) marks the transition stage into sand-hills with their desert types of *Casuarina, Callitris, Grevillia, Hakea, Melaleuca,* and *Epacris.* The 'broken' country has large mallee, big pines (*Callitris robusta*), buloke, and belar (*Casuarina luehmanni* and *lepidophloia*), sandalwood (*Myo-*

porum platycarpum and *Eremophila longifolia*) and a great variety of shrubs (*Heterodendron*, *Fusanus*, *Pittosporum*, acacias, &c.), forming probably the most park-like country in Australia. The so-called spinifex, *Triodia irritans*, the porcupine-grass of the settlers, prevails throughout. Salt-bush plains comprising a large number of the Chenopodiaceæ vary from a few to many thousand acres. Grasses are of the tufty, tussocky order, and rarely form a sod or sole of grass sufficient to prevent sand-drift.

Climate.—The Mallee is arid. Its rainfall varies from 19 to a little under 11 inches per annum, averaging 14 inches. In summer the days are intensely hot and the air excessively dry; consequently there is frequently a considerable drop in temperature at night-time, the range being over 70° F. In winter, the days are bright and sunny with much frost at night, temperatures going commonly below 20° F. Cyclones of destructive force are rare.

Geology.—The surface soils are almost wholly æolian or wind-redistributed; this formation extends to 30 feet and over in depth. They have been formed from lacustrine clays and drifts, which are some 200 feet in thickness. Below these beds, enclosed above and below by estuarial blue clays containing broken shells, foraminifera, glauconite, &c., are extensive marine formations, polyzoal and shell rocks of about the same thickness as the overlying lacustrine beds. Below these are terrestrial fluviatile deposits containing much lignite and pyrites. The thickness of these, which rest upon palæozoic, silurian, or granite beds, is variable, reaching 700 feet. The sequence of beds shows in the Tertiary period a considerable subsidence followed by elevation. While the elevation was in progress and the sea had retreated, the streams at present joining the Murray River flowed in and formed the lacustrine deposits until, uniting forces, they cut a canyon through them to the sea. The Murray River canyon has a depth of 60 to 200 feet, and a width of $1\frac{1}{4}$ to 4 miles. A distinct folding in the whole series of Tertiary beds has been shown by the borings. At the surface these folds are many miles in width and are over 200 feet in height and have a direction a little west of north—at right angles to the sand-ridges—with a marked easterly dip. It is not unlikely that the salt and gypsum areas above referred to mark the synclines, where fracturing allows escape of the artesian waters of the coral marine beds.

Settlement.—There are at present five and a half million acres under settlement, of which about one and a half million acres are under cultivation annually, supporting a population of over 40,000.

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3. *The Experimental Demonstration of the Curvature of the Earth's Surface.* By H. YULE OLDHAM, *M.A.*

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4. *The Central Highlands and 'Main Divide' of Victoria.* By T. S. HART, *M.A.*, *B.C.E.*, *F.G.S.*

A belt of highlands extends through almost the whole length of Victoria. These consist of a peneplain carved out of Palæozoic rocks, and subsequently elevated in blocks to varying heights and dissected. Remnants of older hills above the peneplain are of minor importance.

On these Palæozoic rocks rest fluviatile and lacustrine deposits of Tertiary age. The fossils and relation to marine Tertiaries further south indicate a position low in the Tertiaries for the oldest of these. The formation of the peneplain may be regarded as early Tertiary. In Southern Victoria worn down Jurassic rocks form part of the peneplain. On the Central Highlands and south of them there are also two series of volcanic rocks, known respectively as the older volcanic (early Tertiary) and newer volcanic (late Tertiary).

The central belt of highlands is outside the limits of the Jurassic coal-bearing sediments and of the marine Tertiaries. This area has been relatively high from Jurassic time onward, and has been much more elevated in Tertiary times than the marine Tertiary area.

The general effect produced by the elevation has been a broad belt of highlands falling away to north and south and higher at the eastern end. In detail

this area consists of numerous fault-blocks, more or less tilted, and unequally elevated, producing original crests and valleys. As the crests of the blocks are often transverse to the east and west trends of the whole highlands, the two ends of a relatively low strip may be occupied by streams flowing to north and south respectively. The main water-parting or Main Divide between the north and south streams varies in its relation to the fault-blocks, being determined in part by crests of tilted blocks, or by relatively high blocks, in part by the position of the Divide at the head of streams flowing in opposite directions in the same low area, and in part by volcanic accumulations.

It is not necessary to suppose a single original Main Divide from which streams flowed directly to the lowlands north and south. On the contrary, there is distinct evidence of a more complex arrangement of the original crests so that some areas had less direct outlets—for example, a well-marked east and west crest south of Ballarat is connected by a meridional ridge east of that town to the Main Divide producing two basins, that of Ballarat, and that of the original Parwan; the present southerly valleys of the Moorabool, Yarrowee, and Smythe's Creek are cut later through this southern crest. The presence of original difficulty-drained areas has probably made alterations in the drainage system easier, both by capture and by diversions after volcanic infilling. Alterations are also facilitated by differential movements after the present drainage system was initiated on the rising peneplain.

The Upper Goulburn has probably been formed by linking by capture of originally distinct basins. The same has very likely occurred in the case of the Yarra. The alterations near Ballarat are largely due to volcanic accumulations.

The Main Divide is sometimes volcanic, as in parts near Ballarat, where it is formed by materials accumulated round several vents.

The actual intrusion of the granitic rocks has taken no part in forming the present Divide. These rocks have moved with the others in block movements. They are evidently more likely to be exposed on the peneplain at places of much elevation prior to its completion. Some of these situations would no doubt continue to be much elevated later.

Some of the boundaries of the granitic areas are fault-lines from which the granitic country rises rapidly (Mount Cole, Mount Martha, Arthur's Seat). Some of the Palæozoic dacites also make very prominent hills (Mount Macedon, The Dandenongs). In these cases the hard rocks on the uplifted side still present some considerable steepness due to the original fault-scarp.

5. *A Map of the Environs of Rome of 1547.* *By* Dr. THOMAS ASHBY.

The Vatican Library has, by a recent gift of His Holiness the Pope, come into possession of an important collection of maps and plans. This includes an engraved map of the environs of Rome for a distance of about twenty miles in each direction, on the scale of about two inches to the mile. It bears the date 1547, and is unsigned; but Mr. Horatio F. Browne has discovered the Venetian privilege for it, from which it appears that its author was a Florentine, Eufrosino della Volpaia. It is rather a bird's-eye view than a map, the projection not being accurate, but the details (roads, farms, streams, woods, cultivation, &c.) are very well shown; and it is the largest map of this district known until comparatively modern times. Though it is engraved on six copper plates, and served as the original of Ortelius' map, it has remained unknown until now, and the Vatican copy is unique. Dr. Ashby has written the text to the publication in facsimile made by the Vatican Library in a series which it is now issuing ('Le Piante Maggiori di Roma dei secoli 16° e 17°').

6. *Three Early Australian Geographers, their Work, and how it is Remembered.* *By* CHARLES R. LONG, *M.A., Inspector of Schools, and Editor of the Education Department's Publications, Victoria.*

In Australia, the scope of the geography syllabus, especially that of the State elementary school, is comprehensive, and the time apportioned to the

subject is liberal. Of late years, a feature of the teaching has been the connecting of the physical features of the continent with those who discovered, explored, and named them, and of the towns with their founders and early residents. The map has thus become invested with a human interest that serves to give an attraction to the acquirement of topographical details which it did not formerly possess. This mode of connecting history with geography has also been to the benefit of the former. The strongly established subject, geography, has helped to place the weak subject, Australian history, on its feet. Another effect of adding humanity to geographical nomenclature has been to direct the minds of Australian children, and through them of their parents, to the early Australian geographers. The value to the nation of these intrepid men is rapidly obtaining recognition; and when you add to that recognition the result of the giving over of a day annually on which the exploits of the explorers and pioneers are made the sole topic of instruction in the schools (as is the case in Victoria), you will see that the time is ripe for the erection of historical monuments and for the proper appreciation of those already erected.

Of the many men deserving of recognition at the hands of Australians three stand out prominently, the navigators, James Cook and Matthew Flinders, and the surveyor, Thomas Mitchell. The geographical work of these men was of immense importance to Australia.

There is no record of any visit to the eastern shore of the continent before that of Cook, who charted the coast-line for some 2000 miles with an approach to accuracy that astonishes the hydrographers of the present day when they consider the disadvantages under which he carried it out.

Among Australian explorers he is easily first in public estimation, sometimes, indeed, being credited by those whose enthusiasm is greater than their historical knowledge with being the discoverer of the island-continent. Public admiration has been shown in the memorials erected to him. At Botany Bay, where he first landed on the Australian soil, there is a tablet affixed to a rock, and also an obelisk. Sydney possesses a fine statue. At Cooktown, Queensland, where the 'Endeavour' was careened at the mouth of a river that bears its name, is another obelisk, and a tree is still reverently preserved as that to which the ship was tied. An admirer at Bendigo, the 'Quartzopolis' of Victoria, has placed a statue of the great navigator in immediate proximity to the principal Anglican church. And, soon, the St. Kilda Esplanade, Victoria, will be graced by a replica of the fine statue at Whitby, Yorkshire.

Next to Cook comes Captain Matthew Flinders, who did a greater amount of surveying along the coast of Australia than any other man. In 1792 he began it with Bligh in Torres Strait, to which he returned ten years afterwards. In 1795 he ventured forth with his intrepid companion, Surgeon Bass, in a boat south from Sydney, with the result that he was able to show to the Governor, Captain Hunter, a chart that won his admiration. Then, with joyful enthusiasm, he went round Van Diemen's Land (now Tasmania) in the sloop 'Norfolk,' and, after that, from Sydney to Moreton Bay. Lastly, in the 'Investigator,' fully accredited by the Admiralty, he began to chart the coast of the continent. Starting at Cape Leeuwin, he worked his way patiently along the coast to Sydney, and thence to the north-east of Arnhem Land, at which point the rotten state of his ship made it imperative for him to bring his survey to a close. His charts are so good that subsequent surveyors have had little to do in the way of amending them.

The first of Australia's memorials to Flinders was erected in 1841 by the Governor of Van Diemen's Land, Sir John Franklin, who had been a midshipman on board the 'Investigator.' It stands overlooking the fine harbour of Port Lincoln, South Australia. The people of that State have not forgotten the good example then set them. They have erected a monument on Kangaroo Island to commemorate its discovery by Flinders, a column on Mount Lofty for a similar purpose, and to the Bluff, in the Encounter Bay district, have affixed a plate to recall to mind the meeting of Flinders and the French explorer, Baudin. Victorians have recently awakened to a recognition of the debt they owe to the man who spent a week in Port Phillip Bay in 1802, and whose excellent chart was used by the early explorers of their State. On Discovery Day, 1912,

Sir John Fuller, the State Governor, unveiled a tablet affixed to the granite tor at the summit of Station Peak, near Geelong, on which Flinders stood to survey the bay on May 1, 1802. At Western Port there is a cairn and tablet which were unveiled by his Excellency the following Discovery Day. It commemorates the discovery of that inlet by Bass in 1798, and the first passage of the Strait by him and Flinders later in the year. Lastly, led by the members of the Victoria Branch of the Royal Geographical Society, an effort that will soon be consummated was set on foot some time ago to erect a worthy statue of Flinders in Melbourne.

Thomas Mitchell, who was appointed Surveyor-General of New South Wales in 1827, had seen service with Wellington throughout the Peninsular War, and had been allowed by him to employ his talent for military sketching and plan-making. To this fine training was added a love for his work as a surveyor and explorer, together with much energy. He well deserved the knighthood that was bestowed upon him. Before his death at Sydney, in 1855, he had recorded a vast amount of detail in connection with the physical features of Eastern Australia.

Of his four great expeditions—the first to the north of New South Wales, the second to the Darling near Bourke and then down that river, the third through Western and Central Victoria (his Australia Felix), and the fourth into Central Queensland—the third proved of inestimable service to the young colony by attracting settlers to it. This fact is now being recognised by Victorians. With the Discovery Day celebrations has been associated the unveiling of a tablet to his memory at Pyramid Hill, where he stood on June 30, 1836, and surveyed the charming prospect around him; of a second on Mount Arapiles, which he ascended on July 23; and a third at Expedition Pass, through which he journeyed on September 29. Owing to the enthusiasm teachers are showing in the matter, it is certain that, in the near future, his line of march in Victoria will be well indicated by tablets.

TUESDAY, AUGUST 18.

Joint Discussion with Section C on the Physiography of Arid Lands.
See p. 363.

WEDNESDAY, AUGUST 19.

The following Papers were read:—

1. *Australian Exploration. By* the Right Hon. Sir JOHN FORREST, *G.C.M.G.*

2. *Forest Climate and Rainfall. By* E. A. MACKAY.

3. *Recent advances in the Map of the World on the Scale of* 1:1,000,000. *By* Professor A. PENCK.

The proposal for an international map of the world on a uniform scale has been considerably advanced in the last few years. A conference of delegates of several States held in London in 1910 approved the general scheme adopted by various Geographical Congresses since 1892—namely, the scale of the map to be 1 : 1,000,000, each sheet to be plotted on its own surface and to be limited by parallels at a distance of 4 degrees in latitude and by meridians at a distance of 6 degrees in longitude, the meridians to be reckoned from Greenwich, the map to be a hypsometrical map, the contour lines of which should be given in hundreds of metres. The resolutions of the London conference were carried

out by several States, and maps after the scheme proposed were prepared by Great Britain, France, Italy, Spain, the United States of America, Argentina, Chile, Japan, and in Portugal and Hungary. Much work has been done for the map also in Sweden. At the International Geographical Congress of Rome, 1913, it was seen that these maps showed many differences in their methods and execution, and the Congress recommended a second international conference of delegates of States. This conference was held in Paris in December 1913; the number of States represented at it—34—showed how general the interest in the map had become. The resolutions adopted did not alter the general scheme of the map, but settled many of its minor features.

In Australia the scheme was discussed in 1912 by a conference between the surveyors-general of the different States, and its execution was recommended to the Commonwealth. A map on a uniform but not too small a scale would indeed be of the greatest value to Australia, for there is none at present. The different States have hitherto only maps of their own territory, and these maps are unequal as to scale and contents. One feature is common to all—they do not lay stress upon the representation of morphological features, and our knowledge of the extent and height of the physical regions of Australia is limited. In order to extend the international map of the world to Australia extensive surveys are still necessary. It would be an important result of the scheme for a uniform map of the world if it should excite interest in the hypsometrical surveys of Australia.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read:—

1. *The Development of the Natural Order Leguminosæ—A Study in Palæogeography. By* E. C. ANDREWS, *B.A., F.G.S., Geological Surveyor, New South Wales.*

A study of Leguminosæ indicates that the final separation of Australia from Tropical Asia took place before that of Tropical America from Tropical Africa.

This problem admits of comprehension only by a knowledge of the succession of geographies in post-Jurassic time, the character and home of the primitive types of the Order, the soils and climate which various legumes favour, the principles of plant dispersion by sea and land, as well as the arrest of development in certain types, and the wonderful vitality in others, such as Acacia and Astragalus; these principles are all elaborated in the main discussion.

Geography.—Extensive and low-lying plains of erosion, large epicontinental seas, and genial climate, were features of the Cretaceous geography, while large continents, great deserts, small epicontinental seas, high mountains, glaciated poles, and a general differentiation of climate into zones are characteristic of modern geography.

Primitive Types.—Home, the fertile tropics. Trees or shrubs, of luxuriant habit. Leaves simple, sometimes digitate or simply pinnate. Corolla regular, petals five. Stamens definite, five or ten, free, sometimes indefinite. Style simple, peculiar. Fruit a pod or drupe.

The narrow belt of tropical land extending south of the Equator from Tropical America to Australia, by way of Tropical Africa, Madagascar, and Malaysia, was broken up at its eastern end in Upper Cretaceous time, and, still later, it was broken in its central and western portions. Many remarkable groups of genera were developed from the fertile tropical types as the result of the severe climatic conditions and poor soils of Australia, South Africa, and Eurasia. Most remarkable of these are, in the first place, the Podalyrieæ of Australia and South Africa, which were derived from the tropical Sophoreæ; secondly, the Genisteæ of Australia, South Africa, and Eurasia; thirdly, the Galegeæ of Eurasia; and fourthly, the Acacias of Australia, Africa, and America.

Comparisons of these xerophytic forms indicate that, region for region, they are only indirectly related to each other by intermediate forms to be found in

the tropics. For example, the Podalyrieæ of Australia, South Africa, and the Northern Hemisphere are related to each other through Sophoreæ. The Eurasian types have been dispersed, during late geological time, to North America by way of North-eastern Asia, and thence along the high western plateaus to South America.

Antiquity of Isolation of Australia.- Great genera, such as Mimosa and Calliandra, are absent from Australia but are present in America, Africa, and Asia. The peculiar group of the Australian Podalyrieæ, comprising nineteen endemic genera and about four hundred species, also speaks eloquently of the long separation of Australia from Asia. The history of Acacia also may be summarised in this connection. The genus is divided into Gummiferæ, Vulgares, Filicinæ, Pulchellæ, Botryocephalæ, and Phyllodineæ. Species 700. The Gummiferæ are the primitive type, and are well developed in America, Africa, and Asia, only poorly represented in Australia and quite absent from Europe and New Zealand. They represent the xerophytic modification of a luxuriant Cretaceous plant, with bipinnate leaves, even at a time when the great continents were connected by way of the tropics. The Vulgares are the most important types, numerically, in extra-Australian areas, being abundant in America, Africa, and Asia. They are absent from Australia. The Filicinæ belong to Tropical America. The Pulchellæ and the Botryocephalæ are endemic in West and South-East Australia respectively. The Phyllodineæ, with about 420 species, are Australian. Of these the Uninerves represent the earlier type, and are characteristic of poor, sandy soils. The home was Northern Australia. In the early stages the phyllode was narrow with the midrib forming the greater portion. The Pleurinerves appear to be modified Uninerves. Both types gradually pushed their way into the deserts, into West and South-east Australia, and into Tasmania. The Uninerves established themselves strongly in the cooler regions of the south, while the Pleurinerves, with the Julifloræ, lagged behind and entrenched themselves securely in the tropics. Both during, and subsequently to, the formation of the great plateaus of Eastern Australia many peculiar phyllodineous types were developed, such as the Racemosæ and the Tetrameræ, and these, in part, during the later glacial period, moved northwards along the plateaus as far as South-eastern Queensland; others again adapted themselves to subarid inland conditions. The endemic Botryocephalæ, also, are in the main a response to plateau development in South-east Australia during later and post-Tertiary time. The western alluvial plains of Eastern Australia, formed during late and post-Tertiary time, gave rise to groups of the Pleurinerves, such as the Microneuræ.

In conclusion, Australia has been isolated from Asia for a great period, and the Leguminosæ of the fertile tropics of the island continent are not comparatively recent and derivative, as has been stated, but are examples of types once cosmopolitan, whose development has long been arrested while the great majority of the endemic types are younger and vigorous xerophytes induced by the altered geographical conditions.

2. *Eastern Australian Topography and its Effect on the Native Flora. By* R. H. Cambage, *F.L.S., &c., Chief Mining Surveyor, New South Wales.*

The chain of mountains known as the Great Dividing Range extends throughout the length of Eastern Australia at distances varying from about twenty to nearly three hundred miles from the coast-line. It consists of an uplifted dissected plateau ranging from about 1,500 to 7,300 feet above sea level, the generally lower portions being in Queensland, and the higher in southern New South Wales and Victoria. In general the eastern face is fairly steep and high, and exercises more influence in differentiating the humid climate of the east from the drier climate of the west, than does the actual water-parting itself, which is often only a slight ridge in various positions on the plateau. The effect of the mountains in the south is to create three climates, a humid and dry one on the east and west sides respectively, and a cold one on the summit which acts as a barrier between two floras which would otherwise commingle to some extent at lower levels.

In Queensland a generally lower summit of the plateau, and an increase in temperature owing to the more northerly position of the range, permit the western or dry influence to cross the mountains in various places, and allow many interior types of plants to thrive on the eastern watershed, while the moist-loving or coastal brush plants are excluded from these invaded areas. This invasion occurs in the Goulburn River valley near Cassilis in New South Wales, and at such places in Queensland as between Toowoomba and Brisbane, between Jericho and Rockhampton, and at other points. Where such a mountain passage occurs the moist-loving eastern flora in no case passes through to the west, but in certain instances arrives there by other agencies, and finds congenial surroundings on secluded portions of elevations protected from the west.

The absence of a high range extending along behind the coastal belt in Northern Australia is considered to largely account for the absence of rainfall in that locality during the winter months, and for the sparseness of the brush or jungle vegetation.

The observations in regard to the effects of topography on the native flora indicate that the rainfall and climate in Eastern Australia are very largely regulated by the physiographic features, and the vegetation, after allowing for differences of soils, is chiefly the result of rainfall and climate. It would therefore appear that the removal of the forests would not result in a greatly reduced rainfall, but would probably decrease the number of damp days.

3. *A Recently Discovered MS. by* JAMES COOK. *By* H. YULE OLDHAM, *M.A.*

4. *The Coast of New Caledonia.* *By* Professor W. M. DAVIS.

5. *Southern Alaska and the Klondyke.* *By* Professor ELWOOD S. MOORE.

6. *Australia: its Discovery as evidenced by Ancient Charts.* *By* GEO. COLLINGRIDGE, *Corresponding Member of R.G.S.A., &c.*

1. Early voyages by the Portuguese and Spaniards in Australasian waters, made between the years 1511-36, but not recorded.
2. Reasons for not recording said voyages.
3. Australia named Java Mayor.
4. Discovery, by author, of Portuguese legend on Dauphin Chart.
5. Reasons for distorting charts.
6. Western Coasts of Australia discovered by the Portuguese.
7. Eastern Coasts of Australia discovered by the Spaniards.
8. Main features of discovery.

TUESDAY, AUGUST 25.

Joint Discussion with Sections C, D, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.—See p. 409.

The following Papers were then read :—

1. *Geodetic Surveying in New South Wales and some Results.* *By* T. F. FURBER, *F.R.A.S., &c., Director of Trigonometrical Surveys, New South Wales.*

The above Paper describes in general terms the limits reached up to the present by the Trigonometrical Survey of the State named, the methods fol-

lowed and the order of precision attained, more detailed treatment being confined to three matters which are engaging attention at the present moment, viz., the general question of periodic errors of instrument graduation; the relation between the height of an observed ray above ground surface and the coefficient of refraction; the third matter being a preliminary comparison of the geodetic with the astronomical latitudes, longitudes, and azimuth, for the purpose of estimating the relative forms of the surface covered by the survey and that of the assumed spheroid of revolution.

The survey extends between latitudes 30° and 37° south and longitudes 145° and 153° east, roughly including an area of 100,000 square miles. The fundamental object of the survey as a whole is to provide the positions of a series of points of sufficient accuracy to control the detail surveys made for the purposes of land alienation and administrative surveys generally and at the same time to facilitate map construction. Throughout the work, however, the necessity has been kept in view of observing certain chains of the triangulation with the greatest precision attainable not only so as to strengthen the remainder but to afford data for incorporation with other similar surveys in determining earth dimensions. It is this primary triangulation which the paper deals with.

Base lines have been measured at Lake George and at Richmond, and the Paper refers to the need for further bases of verification owing to the extension of the survey. In preparation for measurement of these, invar tapes have been lately obtained and standardised and the site of one further base (nineteen miles in length) determined on. The angle work has till recently been observed with theodolites (Troughton & Simms) of eighteen inches diameter read by four micrometers, but a 270-millimetre Repsold of the type used in the Geodetic Survey of South Africa has now been installed. For minor details of the methods of observing and reduction the Paper refers to one read by the writer in 1898 to the Australasian Association for the Advancement of Science, the methods there described having been continued. It will suffice here to state that the mean closing errors of the 171 primary triangles is $\pm\ 0''{\cdot}70$ and that applying Ferrero's criterion $\left[m = \left(\frac{\Delta^2}{3n}\right)^{\frac{1}{2}}\right]$ the value of m is ascertained to be $\pm 0''{\cdot}54$, which indicates that the work is of a high order of precision.

The purchase of the Repsold theodolite necessitated an examination of its circle errors which has resulted in a general discussion of such errors. This it is thought may be of interest and has already caused consideration to be given to the possible need for a change of observing routine. As already mentioned instruments read by four microscopes have hitherto been used. The Repsold is read by two microscopes. The mean reading of two opposite microscopes is affected by periodic errors, $\rho_1 \sin (2\theta + \epsilon_1) \quad . \quad . \quad . \quad . \rho_r \sin (2r\theta + \epsilon_r)$, θ being the circle reading. If after an arc 'Circle Left' the telescope is turned over and swung through 180 degrees horizontally to prepare 'Circle Right' the mean bearing of a signal derived from the combined observations will remain affected with these periodic errors. It is the practice on the survey to use five settings of the horizontal circle, each differing from the preceding by 36°. The new instrument has furnished results showing the large range of $4''$ amongst its bearings derived from the different settings. Although the means of bearings derived from the five settings are free from periodic error (other than those involving 10θ, 20θ, ... , it has nevertheless been desired to determine accurate expressions for these errors for various reasons, and particularly with a view to estimating the accuracy of the graduation of the horizontal circle. An analysis shows how expressions for these errors may be determined from the observations of horizontal angles. From observations made at trigonometrical station Rocks to 23 beacons the value $-2''{\cdot}19 \times \sin (2\theta - 55°)$ has been derived for the first term, while from others at station Ovens to 17 beacons the value found is $-2''{\cdot}11 \sin (2\theta - 53°)$. The terms containing 4θ and 6θ seem to have an amplitude of $0''{\cdot}3$ or $0''{\cdot}2$. Combining all the results yet available the correction to a microscope reading of the horizontal circle is, as far as has been determined, $-17''{\cdot}4 \sin (\theta + 101°) - 2''{\cdot}2 \sin (2\theta - 54°) - 1''{\cdot}0 \sin (3\theta + 228°)$. . . . There is no suggestion in this series that the amplitude of the term containing $10\,\theta$ is of any importance, and it is highly probable that the five

settings of the circle are quite sufficient to eliminate in their mean all appreciable periodic errors.

In the paper already mentioned as having been read to the Australasian Association in 1898 the writer referred to an apparent connection between the heights of the lines above the intervening surface and the values for the coefficient of refraction derived from the reciprocally observed zenith distances. The extension of the survey since 1898 has given further data which generally bear out the conclusions then derived. These data and the results are dealt with in the present paper. In the absence of a topographical survey from which to ascertain the height of each line above the intervening surface the observations have been grouped in the order of length of line, the assumption being that generally the longer lines are the higher. Another grouping has been made in which account has been taken of the height above sea-level on the assumption that the higher regions are the more hilly and that there the height of the ray above surface is the greater. Both groupings would seem to indicate that where information as to the highest above surface is lacking varying coefficients of refraction may be assumed according to the lengths of the lines observed. Diagrams are given showing the variations.

The survey has been computed from the Sydney Observatory (Lat. 33° 51′ 41″·1 S.; Long. 151° 12′ 23″·1 E.) as origin. A map accompanying the Paper shows the extension of the survey therefrom southerly about 240 miles to the Victorian border, where it connects with the triangulation of Victoria, westerly about 360 miles to the limits of the almost flat country of the interior, and north-westerly towards the Queensland border a distance of 240 miles. The map shows also the differences between the geodetic latitudes, longitudes, and azimuths as derived from the assumed earth dimensions (a modification of the Clarke 1880 spheroid) and the corresponding latitudes &c. obtained by astronomical observation. These show the effects of local deflection of the vertical caused by irregular distribution of surface-masses. Broadly, New South Wales may for our present purposes be said to be divisible into three zones, the littoral of from 20 to 60 miles in width rising from sea-level to 2,000 feet in height; at the rear of that plateau 100 miles in width varying from 2,000 to 3,000 feet in height, with mountain masses up to as much as (in the southern extremity) 7,000 feet, and westward of that a more or less gentle western slope to interior plain country. As the result of the attraction of the central elevated mass and of the defect of gravity of the adjacent ocean it would appear that along the coast there is a general eastward deflection of the zenith of about 10″ with a corresponding westward deflection on the western slopes ranging up to as much as 17″, but gradually diminishing as the flat country is reached. In 1898 a general reduction of the data then available was made for the purpose of obtaining an idea how far there was conformity between the actual surface and the assumed spheroid, but the survey was then too much limited to the eastern slopes to afford satisfactory evidence. With the subsequent extensions of the survey, however, a much more useful discussion of the subject is within reach, and it was hoped that by now bases of verification on the outskirts of the work would have been measured, when it would have been possible to reduce the whole work with the object of enabling such a discussion to be made.

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2. *The Sand-Drift Problem on the Eastern Coast of Australia.* By G. H. Halligan, *F.G.S., Inspecting Engineer and Hydrographer, N.S.W.*

The scientific, as well as the commercial, importance of a full knowledge of the direction, volume, and velocity of the movement of sand on the eastern coast of this continent is sufficient warrant for the labour and cost expended upon it by the author during the last thirty years.

There is undoubted evidence of the sinking of the eastern coast of Australia during recent geological time to the extent of 200 to 300 feet, and the natural result was to leave a very uneven shore-line, with many outlying islands, deep bays, and rocky capes. Had there been no ocean current, running parallel to the general trend of the shore, the sand and shingle, resulting from the

disintegration of the land by chemical, meteorological, and mechanical means would, of course, have been distributed by tides and waves, and would have formed sandy beaches in the immediate vicinity of their origin. The form of the beaches in the neighbourhood of granite, basalt, shale, or sandstone would have been readily recognisable; but such conditions do not exist, and the author endeavours to show that the resultant outlines could not assume the contour of the present shore-line, but are the natural consequence of a continuous travel of beach material in one direction.

The Eastern Australian current, which first strikes the Australian coast between Hervey Bay and Moreton Bay, has a velocity of from one to two knots, with very little seasonal variation. Some of the salient points on the coast tend to produce eddies, which have the effect of changing the outline of the sandy foreshore and diverting the course of the rivers, but, in the main, the direction of sand-movement below high water must, in consequence of this current, be from north to south.

The effect of the travelling sand impinging upon the islands and reefs, and its accumulation in the form of banner-reefs, hooks, and tongues, &c., are described, and the result shown on the accompanying map. The map shows the boundary of the old rocky coast at the time the last subsidence of from 200 to 300 feet took place, and its relation to the existing foreshore. The intervening space is partly or entirely filled with sand of marine origin, although covered in places with several feet of humus, which forms some of the richest land of our coastal area.

On certain parts of the coast the sandy beaches take the form of the Greek letter 'Zeta,' the resemblance becoming less as the speed of the current decreases.

The significance of this 'Zeta' curve, in its relation to harbour engineering, has been referred to by the author in another paper, as also the necessity for differentiation between ocean and tidal currents as they affect sand movement at river and harbour entrances.

The volume of sand travelling down the coast has been computed from measurements made at the Clarence River entrance and at Port Kembla, and the effect of varying weather conditions upon the movement is referred to.

Some measurements of the sizes of the sand-grains and their geological origin are given, for the purpose of supplying data for comparison with similar areas in other parts of the world.

3. *Central Australia and its Possibilities.* *By* W. H. Tietkens.

That part of Australia to which reference was made lies for the most part between the parallels of 24 deg. 20 min. and 30 deg. 35 min. South Latitude, and between 123 deg. and 133 deg. East Longitude, embracing an area of about 378,000 square miles, considerably greater than the area of New South Wales. This immense area may be described as a sandy depression, in places perhaps not much above sea-level, where the sand-hills or sand-dunes in some instances may be 100 feet high, and it has been called the 'Dead Heart of Australia.'

So much has been done in reclaiming these so-called desert tracts in other countries that it would be well to turn our attention to the enormous area at our door. These sand-hills occur in confused groupings, also in nearly parallel ridges, but these will not be found to prevail west of 127 deg. East Longitude. West of that meridian, with few exceptions, the country is more level—soil firm and hard loam, nodules of iron-stained gravel, robust vegetation, spinifex, mulga, desert oak, and other Casuarina. The object is to point out from personal knowledge where such schemes of irrigation can be best effected, and which, if carried out, will in time develop and make profitable that which has hitherto been regarded as a desert waste.

Possibilities are suggested from the fact that native wells are sometimes the remains of mound springs. These springs, we learn, are the natural outlet of artesian waters, and from that it would seem that the artesian basin may here be nearer the surface than has hitherto been observed in Australia.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION.—Professor E. C. K. GONNER, M.A.

MELBOURNE.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

THE subject which I wish to discuss to-day has been determined for me by the circumstances of the present meeting of the British Association and by the trend of modern economic study and research. We are meeting for the first time here gathered together from distant and diverse parts of the world, and in this Section at any rate we shall be discussing problems similar in certain respects in our various countries but unlike in other respects owing to the differences between those countries. It is a fortunate circumstance, because it is largely by means of an interchange of views and experience acquired in such different environments that true knowledge can be surely attained. On the other hand, it can be said, I think, without any exaggeration that of the economic studies of the last twenty years none have been more fruitful in result than those which have dealt with economic development as it has taken place in the past and as it is taking place in the present. Economic laws, which, after all, are but generalisations of the relations between different factors or of the relations which exist between certain causes and certain consequences, are studied increasingly in connection with particular periods, movements, and countries. New forces and new features present themselves, and with their introduction we perceive a change in results. This at once teaches the relativity of many economic maxims and statements and disproves the assumption, which at times some have been prone to make, that all nations and all countries undergo a uniform process of development and respond in a uniform way to any given action or policy. It throws some light, too, upon the nature of these laws. Economic laws are not invalidated because conclusions alter as premises alter. But, on the other hand, such changes necessarily bring with them alterations in the rules laid down for practical guidance.

We come then to consider the particular economic features which characterise countries passing through the early stages of economic evolution during modern or recent times. Such countries, it need hardly be said, stand in a marked contrast to the older countries which surround and confront them and which have all already passed into further and more advanced stages. They differ also in their economic circumstances—and this is what needs special emphasis—from those same countries when in the primary stage of growth in the past.

But to bring the matter within the limits of an address it is necessary at the very outset to define a little carefully the scope of the investigation. New countries differ greatly among themselves. Speaking broadly, they fall into three chief groups. There are tropical countries unfitted for white settlement and marked out by their characteristics for a very specialised development. Again, there are countries like some of the States of South America where, owing to particular features attending settlement, or to climatic and other causes, a growth at all comparable to that which has taken place in Western Europe is

retarded if ever practicable. Lastly, we come to lands like Canada and Australia, and with these may be included the United States, where considerable similarity to the older countries exists alike in antecedents, circumstances, and prospects, though in each case there are undoubted and specific economic differences. I purpose, therefore, while not wholly excluding from our survey countries of the two former types, to direct your attention in the main to the last-mentioned type, in the hope that by an examination so defined, and a contrast of countries of this order with the old European nations, some light may be thrown on the causes underlying the more striking dissimilarities in development.

Before, however, the economic features and differences distinctive of new countries are dealt with, it may be well to say a word or two as to the general course of early economic growth in England and other European countries. Three features call for particular mention. In their early stages these latter countries were free from any continuous external contact and interference; their relations with each other and the outer world were slight, or at any rate not such as to fundamentally determine the direction and nature of their development; they had to meet their own wants and to do this by means of their own resources. Secondly, during this period the nation itself was composed of small and almost self-subsistent and self-contained groups. Lastly, economic methods, social ties, and intellectual attainments were on the same plane, being simple and, as we now should say, backward or primitive.

When we turn, however, to the position of new or young countries either at the present day or during recent years, we are met at once by features which stand out in significant contrast to those sketched above. Not only are such countries in the early period of evolution, but they are in continuous contact with other countries, and, moreover, with other countries which are in a very different stage of development. Again, they are young countries, in some instances inhabited largely or wholly by people, in other cases guided and controlled by leaders, modern in every respect and sharing to the full in the science, knowledge, and ideas dominating the older countries. Furthermore, both their social and their political features are modern; on the one hand, these are not of the type which in the past were associated with the early stage of growth; on the other hand, the countries themselves are much less affected than are older countries at the present day by traditions and customs which, despite their origin in the circumstances of bygone days, still continue to influence the life of the present. In other words, they are less helped or less hindered by habits of long formation. But these somewhat general considerations are but preliminary to a closer and more careful analysis of the particular economic conditions which beset countries now in the early years of growth.

Firstly, such countries, even in the earliest stage, are unavoidably in close relations with countries which have attained a more elaborate growth and organisation: communication renders isolation impracticable, and every year the means of communication increase. It is a question, not of intentional interference, but of that inevitable influence which nations in close relations bring to bear upon each other. Nor is it a question of one-sided influence. Older nations have been and are affected in their economic policy and organisation by the discovery and opening up of new lands and by the events taking place in them. Still, it is probable that the influence of the older-established world is more powerful, so far at any rate as the direction of economic progress is concerned. Be this, however, as it may, it is this aspect which occupies our attention at the present moment. The effect is particularly apparent in trade and industry. Needs, in other words, are not dependent for their specific satisfaction on the internal resources and productive activities of the particular land, and this, while important in all instances, is of great moment in the case of a country which, as yet without opportunity to develop its powers, is seeking, as it were tentatively, the best lines of advance. It is peculiarly open to influences of this kind, because its organisation is not firmly established. When the social structure is less complete and the direction of development uncertain, the risk of future and permanent advantages being outweighed by present gain is enhanced.

Secondly, in the opening up of resources, the former dependence on the internal powers of the country has been essentially modified. Both capital and labour can be obtained from outside. This, of course, quickens development;

but at the same time it may affect its direction. Certainly it introduces many fresh problems; and sometimes these are very difficult problems. Taken as a whole, it leads to a very rapid or sudden development, an aspect of peculiar importance where what we call native races are concerned. Quite apart from certain evils often associated with such alien intrusion or dominance, and apart too from the shock occasioned by the introduction of foreign standards and customs alongside of or in substitution for old usages, such people often have manifested an inability to stand the mere pace of modern progress. Even when we come to white races, the results of the rapid progress which occurs when natural resources are rich are open to adverse criticism. Again, it may lead to too great a concentration on particular methods of production and particular occupations, to the exclusion it may be of other methods and occupations which ultimately may be more advantageous. Again, stable customs and social ties are more difficult to form when industrial development is hurried. In addition to these, other special difficulties manifest themselves in the respective cases of alien capital and alien labour in new countries. So far as capital is concerned, the case varies according as the introduction of foreign capital is or is not accompanied by the introduction of those who control the employment of the capital, and so the industries in which such capital is used. Even when alone an interest on the part of outside nations is often awakened which is not wholly healthy, extending sometimes to attempted political influence, though this, it should be said, is not of frequent occurrence except in the case of countries largely native or semi-native or occupying a very backward position in the scale of civilisation. Sometimes, too, it may occasion the premature exhaustion of particular sources of wealth, or at any rate rather in the interests of foreign capitalists than of the inhabitants themselves. But in the case of the more backward countries, and especially of countries where climatic conditions preclude a white population occupied in manual work, it has usually meant the introduction of a class, controlling capital and organising industry, and yet entirely alien to the main body of inhabitants. Such a situation undoubtedly imposes a great responsibility on those in whose hands lies the social and political government of the country, a responsibility still greater when the organising class does not settle down, but comes and goes in a bewildering procession. British India and the Dutch Indies furnish illustrations; and, to some extent, the effect of such a tendency is to be perceived in certain parts of South America. Nor is the immigration of labour from other countries less complex or less potent in its results. Such labour comes from many sources and varies greatly in kind. A clear distinction, however, must be drawn between white labour not essentially different from the existing white population and more or less skilled or otherwise adapted to good manual work, and, on the other hand, labour of a lower type, often racially distinct and in some cases brought in owing to its climatic suitability. So far as the former is concerned, immigration as a rule is attended with few difficulties other than those of a simple economic character and more or less temporary in their nature. A ready means of stimulating industrial development is provided, and the country is supplied with skilled adults without the cost of education and upbringing. But the results of immigration of the second type of labour are less simple. The general question of immigration, indeed, may be looked at from three points of view. From the aspect of economic employment, immigration often involves immediate competition with the labour already in the country or coming forward with the normal increase in the population. But in a new and progressive country with many openings for new developments such competition is seldom harmful. In the long run the labour creates its own field of employment and contributes towards the general progress. At times, it is true, the supply may be in excess of the demand, and any particular kind of labour may continue to stream in long after the need for it has ceased. But this can be remedied best by the wider diffusion of accurate knowledge as to the conditions and necessities of the place in question. Positive restriction, if attempted, may do harm by obstructing supplies of labour when needed in the future. When, however, economic standards of living are considered, the kind or type of labour in question is all-important. Ordinary white labour entering a country already peopled with white men offers little difficulty. But nearly all nations have encountered difficulties

when any considerable immigration of labour occurs from countries where the standard of living is essentially and, as it were, permanently lower, and these are rendered graver when accentuated by difference of race. In old and new countries alike the entry of a low type of foreign white labour may bring about a lowering of the general standard in certain industries or certain places, with harm, not necessarily limited to the district or employment in which it settles. Still, apart from the more general considerations of policy, interference would probably involve restriction of the more desirable type of labour already dealt with and thus be economically disadvantageous. The case of coloured labour is admittedly different even in this respect. Standards vary and the racial barrier seems to prevent their speedy adjustment. But the difficulties of the whole matter are shown more clearly if we turn to consider immigration in its relation to general social progress and political government. Here the main point is the possibility of assimilation. How far or how easily, it is asked, can such new elements be absorbed into the general life and made an integral part of a homogeneous population? Now, it is not my business to discuss the question in detail, still less to examine any particular policy which may be advocated or which may have been adopted. All that is necessary is to note this difficulty and to emphasise its existence in the case of new countries and especially of those countries or places where labour of this type is required or attracted by reason of climate or other like causes. Two considerations may come into sharp conflict: on the one hand, the rapid production of wealth may be assisted; on the other hand, serious effects in respect of economic progress, nationality, and orderly growth may be experienced.

In no country, it should be added, has the question of the supply of labour from outside played a more important part in economic history than in Australia. During the early period not only was it one of the influences which tended to the continuance of the transportation system, but it was, if not the chief, one of the two chief factors in the policy of colonisation and settlement devised and advocated by that very distinguished man, Edward Gibbon Wakefield. In more recent years it has been associated with state assistance, and also with forms of indentured labour. And it remains one of the problems before the country.

Thirdly, modern methods and modern science are applied to production even in its early phases, to agriculture and the extractive industries as well as in trade and manufacture. The consequences are both many and great. Rapid and sudden growth is rendered possible, but this, as already indicated, results in consequences not always or wholly advantageous. Such effects are the more evident when the natural resources of the country are rich. Furthermore, when such occurs there is an invariable tendency to substitute large-scale systems of production for the small-scale systems characteristic of production in the past when in an early stage, and this is not without significance both economic and political. No doubt this is of greater moment when a development of this order takes place in a land peopled by native races, who are forced, as it were, into a system wholly alien to their social surroundings, and one which they fail to understand. There is a disastrous incongruity between their method of employment and their social environment. Though of less it is still of some importance when the population itself is modern in civilisation and outlook. To some extent, but only partially, they inherit from their ancestors in other lands the lessons slowly acquired in the time of small industry and occupation. On the other hand, there can be no doubt that the more rapid progress due to the reasons given, accompanied as it is by greater vicissitudes, offers a more general opportunity of success to those willing to work hard than is possible in other countries. Rapid progress always tends towards this end, and it does so the more especially when the organisation is more flexible and less marked by custom. Not only is the field itself wider, but the changes in the field are more frequent.

The difference in economic development, thus briefly depicted, implies, it must be remembered, a somewhat parallel difference in administrative and political life. If we take such a country as England, small-scale production was part and parcel of a system in which small local communities grew up practically self-contained and self-governed. Thus the strength of the Government rested largely on local administration which made its influence felt in the

general and central administration. But in a young country developing under modern conditions the system of local administration is consciously devised. It rather derives its existence from the central Government than furnishes the material out of which this latter is gradually evolved.

Fourthly, a modern new country has before it the example of older countries which, after passing through the phase in which it is, have developed the more complex economic system towards which it is tending. Their conditions and institutions record the results of forces which, though nascent in it, are yet in operation. It may have something to imitate, it certainly will see much to avoid. This is true from many points of view. It is true in a technical sense. Everyone knows the importance of ruthlessly scrapping plant; but there are parts of the national plant, as it were, which cannot be scrapped. Though neither the English railways nor the English canals if laid out anew would be constructed on their present lines, they are too elaborate and costly to be destroyed and reconstructed. It is equally, if not more, true when we consider the industrial system in its more general aspects. In this instance we know that Germany, to take an instance, enjoyed one advantage because her development followed, and was not contemporary with, industrial development in England. Perhaps it is truest of all in respect of the social consequences of industrial development. Take, for example, the large cities and manufacturing districts in the old countries with all their social problems; housing, sanitary, and social. A country in the early stages is in this truly advantageous position that action in its case means provision and not reform. Hence the crucial importance at the present time, in such a country as this, of the Town Planning movement. Again, there has occurred, in those lands in which manufacture has made its greatest strides, a gradual exodus from the rural districts, partly no doubt because of the larger wages to be obtained in the towns and industrial districts, but partly owing to a past, if not present, disregard of agricultural interests, and to the comparative lack of attraction in the country. It may be looking ahead to suggest that such may affect a country like Australia; but time brings many changes. In any case the time to provide against a movement such as this is not when it has acquired force, but when agriculture is prosperous and before town life has begun to exert its curious lure on the population.

Fifthly, older nations became critical and self-conscious at a comparatively late stage in their history; that is, after customs had been formed and structure had lost its former flexibility. In such cases remedial movements and changes, however wisely initiated, encounter a natural and quite comprehensible conservative opposition. Whatever their possible gain, in the progress towards this destruction is involved. Nor is it incorrect to conclude that in many instances the immediate and certain losses rightly outweigh the problematic if ultimate advantages. Far otherwise is the case in a new country where the period of self-consciousness begins with the early days of growth, and conscious action towards a given goal has an easier path and suffers less from the knowledge that it must destroy in order to achieve. Even if social experiments fail, in such countries they cost less than they would in countries more stable and more firmly based in habit and tradition. Of course, there is loss as well as gain in this. In the one type of country there is greater stability, in the other greater confidence or courage in novel directions.

Lastly, and following to some measure on what has just been said, we have to take into account the smaller part played by social conventions in the economic life of new countries. In older countries, primary development took place under conditions as to social life and order not due wholly to economic causes, but often arising from reasons which existed outside that domain. Social position, accepted without question, and forces like caste, rather indicated what various classes were to do than grew out of the necessities or nature of their respective occupations. No doubt some correspondence was required, since regulations unsuited to progress led to the supersession of the races less apt to meet the needs of the time, and so the usages which survived bore the stamp of economic fitness. Still, in the main, economic activities rather followed than created class divisions. But the economic situation changed, and thus in later years we have the curious spectacle of distinctions which have survived from the past and with time lost much of their meaning, lingering on side by side

with class distinctions resting wholly on economic success. In a new country not only are traditions weaker, but from the beginning economic success plays a larger part. Thus, social prejudices as to the standing or respectability of varying occupations are less strong. Again, owing in part to circumstances of this order, work of some kind is to a larger extent the normal lot of all, a feature which cannot but play a great part in the development of the country. The existence of even a small idle class is anomalous. On the other hand, there is the inevitable drawback that material success, or, to put the matter bluntly, wealth, has less to counterbalance it than in lands where traditional position still holds a place. It is quite true that in England the same or a like tendency has been marked in recent years. No doubt, too, this danger, and it is a very real danger, is best met by the erection of finer ideals and loftier standards of conduct and attainment than are furnished by considerations of birth and traditional position; but meantime, and pending their growth, the latter, at any rate in old countries, does something to lessen the importance and influence attached to wealth as a thing in itself. Even in new lands, such as the United States, and no doubt to some extent in Australia, they are not without a certain influence, but they are in an alien atmosphere. Hence the particular importance of the creation of a real standard of culture and personal excellence.

Hitherto it has been my task to state and describe the chief economic particulars with regard to which countries of various types differ. It is now necessary to examine these in other ways and especially as to the influence which taken together they exert upon the economic progress of what we have called new countries. To do this at all fruitfully necessitates their consideration with regard to three matters—namely, the direction of economic development, the industrial organisation, and, lastly, the national life and character.

The first question to put, then, is the special effect of these factors upon the economic occupations and interests of such countries. The natural answer which will occur to any economist is that countries in close contact and engaged in trade tend to develop those industries and occupations in which, as compared with others, they enjoy special advantages or stand at the least disadvantage. Such a distinction or division of industries, of course, exists between foreign nations and is the basis of the theory of international trade. But in the case of young countries its features and consequences are accentuated and bear a particular significance: with them it means that almost inevitably and before manufactures have been initiated, let alone developed, they will enter upon a course complementary, as it were, to the occupations embraced in older countries and corresponding to the needs of such countries, the direction of their growth being determined by the interaction of external needs and their own natural wealth. This is in the main the so-called 'infant industries' argument; but it is important to observe in detail the many causes which make up the strength of this when applied to the case of young industries in a new country. The circumstances of such countries usually offer peculiar advantages in some one or other branch of agriculture, sometimes, too, in mining. If the case of agriculture be taken, such countries possess, as compared with older countries, abundance of land in proportion to population, while in addition the soil is new and often rich. The truth of this may be seen by a reference to Australia, Canada, the United States, Chile, and the Argentine. In all these, the agricultural advantages, and in some those connected with mining, are great. Consequently foreign capital is attracted into these directions and suitable foreign labour is needed and obtained. Sometimes in the case of settlers the two come together. The great strength of agriculture in these instances lies in the application of modern scientific methods of farming and the use of machinery where land is plentiful. On the other hand, new countries are unfavourably situated for the prosecution of manufacture. Not only would they encounter the competition of manufactures already long established, highly organised, and victorious over the initial difficulties involved in such a development, but they are lacking in two great requisites. They lack a population trained to manufacture and with some degree of that acquired skill which is attained from an industrial environment. Further, manufactures depend to a great extent on the degree of general organisation in the country as a whole, which includes, not merely skill, but the development of those conditions and

means which are necessary to highly skilled industries, providing it with ready carriage, organised markets, and credit. Such a system is only evolved slowly, and in its absence, or while it is weak, the struggle for success is necessarily severe. Under such circumstances the line of least resistance is obvious and the forces of individual action and of competition drive a new country into this direction. At this date it is fortunately necessary to deal only with the normal forces which bring about what has been called a complementary development in new countries. Still, it must be remembered that from time to time suggestions have been made which are, to say the least, reminiscent of the ideas underlying the old 'colonial system,' which sought by political measures to compel colonies to develop along these lines, that is, so far as the circumstances of the time in respect of locomotion and carriage allowed.

The errors of the old 'colonial' policy may seem evident to us, but if so, it is because they were emphasised in its disastrous consequences.

When scientific colonisation came into debate, with the nineteenth century, there was no thought of attempting any revival of the system just alluded to. On the contrary, one of the first subjects to attract attention was the possible undesirability of too one-sided a development. This was looking at the matter from the point of view of the new country itself. To some writers greater variety of occupation appeared advantageous, and with this end in view schemes were propounded for the establishment of town-settlements and other forms of industrial development.

Both old and new countries may be said to suffer under disadvantages in this respect, but the disadvantages point in different directions. The maintenance and extension of rural life is demanded in England, for instance, whereas in new lands the demand has been expressed for the encouragement of manufacture. Alike from the economic as from the more general point of view, the development side by side of activities so different in their direction, and so admirably fitted to supplement each other in their influence on national life, may seem desirable. In a community, as in an individual, many elements are required, and these, it may be contended, can be permanently secured only by a variety of occupations and interests. Though this is a matter for argument, here it is sufficient to observe that the question exists and that with it is raised the advisability or inadvisability of state action to prevent too great a concentration in one direction and to foster other occupations which, however great their success may be when well established, have little or no chance of surmounting the difficulties attending them in the earlier stages.

When we turn to industrial organisation and especially to the question of the relations of labour and capital, certain matters may be briefly mentioned and then dismissed. In some new countries foreign capitalistic interests predominate and introduce difficulties partly economic and partly political in character. Again, the entry of low-grade labour and particularly of coloured labour creates the peculiar dangers which attend a rigid and especially a racial separation between different economic classes. Here again the problems are partly economic and partly political. But these, though undoubtedly grave matters, are somewhat special and by no means universal in new countries. It is more important, then, to consider how far the general problem of the relations between capital and labour is likely to be affected by the particular characteristics which have passed under review.

A greater emphasis on the rights and claims of labour is only to be expected, and is due to various causes. Certain of these are particularly important. There is a smaller body of labour in a position of personal dependence, a factor greatly accentuated by the opportunities of change which present themselves. So there is a greater independence of attitude. Again, work and economic occupation play a very large part in the general life of the country. When such is the case, public attention, and so general interest, are attracted to the conditions and the remuneration of labour. This attitude should be carefully distinguished from that due to the human sympathies awakened by the spectacle of distress and misery. It shows itself less in attempts to alleviate personal suffering and more in the determination to secure for labour what is considered to be its rightful position. Justice rather than mercy is its characteristic. On the other side, there is no great mass of inherited traditions. It was

explained before that social or class traditions are derived, at any rate in part, from a time when position was due less to economic reasons than to causes inherent in the structure of society. These remain on in a changed economic environment, with the result that certain grades in the economic hierarchy tend to become the partial monopoly of particular classes. Hence a separation and a tacit opposition between certain classes with their economic development and other classes. Countries which have escaped the earlier stage are less affected by considerations of this kind. Furthermore, the present industrial condition of older nations is not without effect as an example. The public evils of low-paid labour brought up in bad surroundings are an illustration of what is to be avoided. It is correctly seen that it is easier to anticipate such consequences by avoiding the conditions which lead to them than to remedy them when produced.

There is another circumstance which, though by no means universal in new countries, tends in the same direction. The effect of different systems of land-ownership and occupation upon the position of labour calls for attention in countries of all descriptions. Speaking generally, it may be said that free access to the land and the existence of small ownership, or to a less degree of other means of small cultivation, add to the freedom and increase the independence of those employed, not only on the land but in all occupations. In this respect there is no doubt much difference between countries of the kind under discussion. Still, on the whole, the greater abundance of land as compared with population and the recentness of land legislation offer in such countries a wider and a better alternative to industrial and other wage-paid employments than exists in several of the older and more settled nations, and hence increases the independence of the classes concerned.

On the other hand, certain of the circumstances which give strength to this movement on the part of labour affect in a marked way its nature and its course. Better opportunity and less rigid separation between industrial classes will bring with them in the long run a sound appreciation of the many and various factors which combine in economic development. The tardy rise into prominence and power of the labour movement at a late date in the development of old nations involves one very real danger which new countries have, at any rate, the opportunity of escaping. With the existence of a marked separation between the various industrial classes, attended as that is by features of distress and less relieved than in new countries by equality of opportunity, it is difficult to secure an equable and unembittered consideration of the economic importance either of capital or of the skill which directs, controls, ventures, and organises. The hardships and inequalities obvious in the system, when coupled with the long existence and apparent permanence of the industries, lead not unnaturally to an under-estimate of these as factors and to a keen feeling that the one thing necessary is a new distribution of the national wealth. In these respects new countries have initial advantages. Their greater vigour begets a pride in the progress of the community and in the industries and occupations which embody and signalise that progress; while more widespread opportunity, and the sense of being at the beginning of things, should make them conscious that it is their task to devise a system both equable and commercially progressive. Still it is one thing to have an opportunity and another to utilise it well.

There are, it is true, certain circumstances which for a time may obscure or even hold in abeyance this very necessary endeavour. When rich resources are being rapidly opened up and when prosperous undertakings press one upon another, people are too busy and too well-off to pay attention to economic problems, despite the future importance of their solution. The return to the various factors, both capital and labour, is nigh, and there is little complaint as to lack of opportunity. It is largely due to this that, even amongst new countries, the part played by the forces of labour, and the claims made on its behalf, vary so much. Again, no doubt, the political machinery has a great influence. A country where the professional politician rules, or where the caucus exerts its sway, is little likely to develop a sane and well-timed industrial policy.

The effect of economic conditions on national life and standards is a subject

which merits much attention, but here I must confine myself to distinguishing certain results or particular economic features which characterise one type of country. Some of these, indeed, despite their importance, must be treated very briefly. Thus, for instance, the effect of a rather one-sided economic development, already treated of in another connection, has a bearing on the present matter. Again, the difficulties which some new countries have experienced, in respect of the immigration of a particular type of labour, are undoubtedly attended by social and political risks. No nation can view with equanimity the steady increase of an element in the population which stands out apart and distinct from the nation and can neither assimilate national characteristics nor be absorbed into the national life. Remedy may be difficult, but such a situation is undoubtedly disquieting. But if we leave these, as matters already dealt with, there are four matters which call for attention. In the first place, the circumstances of a new country, if that country be at all prosperous, naturally engender self-reliance and vigour. The openness of outlook, and the obviousness of the progress achieved, make for assurance and hopefulness. Even if vicissitudes be frequent, and men lose as well as gain and fall as well as rise, we only come to Adam Smith's position when he attributed the stimulating effect of great prizes in any occupation or calling to the innate sanguineness of human nature, which leads each man to believe in his own prospects of success, whatever may be the fate of average mankind. And where the examples of success are many, this individual hopefulness is much strengthened. So, too, the greater diffusion of opportunity plays a part. What is characteristic of the individual is characteristic of the race. Of course, there are some new countries where a lack of rich resources precludes any such feeling, and in any country there must occur from time to time periods of depression, perhaps the more acute because of their vivid contrast with the sanguine past. But, taken as a whole, undoubtedly in new countries, where development is in active progress, there is greater vigour, greater assurance, perhaps greater self-assertion, than in other lands where development has gone further and where the prospect lying before the race as well as the individual is bounded by what seems to be a nearer and a more defined horizon. In the second place, as work is the common lot, there is less division between calling and calling and more tendency to judge a man by what he has done in his occupation, whatever that may be. A factor like this is far-reaching in its influence and reveals itself in many directions. It makes for solidarity, as well by creating a community of interest as by destroying prejudices. It furnishes a common test whereby pretensions and claims for consideration can be tried; and, though the measure may be imperfect, the test of actuality, after all, has the merit of being definite. In the third place, in such communities material things and material interests necessarily loom large. This points to a weak feature in this phase of development which is emphasised by the circumstances of a country striving to make good its place amongst older nations. The very pressure of their demands and their competition add to its prominence. Success means material prosperity. There can be little doubt that this is one of the dangers against which a community of this type has to strive. Such a country is, by the very nature of things, face to face with material difficulties and its victory rests on material achievements. Even the democratic test, alluded to above, of actual work and achievement operates in the same direction. In the last place, the very freedom from class prejudice is in part due to a general absence of custom and tradition which has an unfavourable as well as a favourable side. From a social point of view, custom is an invaluable tie, welding into union a large body of individuals with every variety of aim and very different views and opinions. It gives a permanence and stability to social life. No doubt, each country has to form its own habits, but till these are formed the social structure is weak. As an illustration, a comparison may be made between legislation in a new and in an old country. In the latter, legislation is largely a gradual development of custom, and as a consequence the course of legislation is slow, often injuriously slow; the delay in some cases being due to an unfair regard for vested rights; but the main reason is the latent dislike to any violent breach with the past and to departures from custom. On the other

hand, legislation in a new country is much more conscious. Not only are there fewer customary bonds, but there is less regard for those which there are. I do not wish to pronounce any opinion as to the net advantages of one method or the other. The point to be emphasised is the existence of a difference in this as in many other respects.

To what, it may be asked, does the examination summarised under the foregoing headings point? In the first place, it gives some grounds for and explains the nature of public action as it has manifested itself in these countries. Now, an active state policy in social and economic matters may be due to many reasons. *It may arise from an imperfect individual development, or, again,* from what seems at first sight nearly the same thing but is really quite different —the existence of a highly organised and peculiarly efficient bureaucracy. But neither of these is true of the principal countries under consideration; in the United States, Canada, and Australasia, individuality is a very vital force, and the tendency of government cannot be termed unduly bureaucratic. The latter point may be illustrated by a comparison with modern Germany, which has been influenced so greatly by the system of bureaucratic administration built up by Stein and his successors. Of course, good officials can always achieve a great deal, but it is one thing to use officials and the official system as instruments to give effect to a policy, and another to take a policy from them. It must not be supposed, however, that democratic countries are altogether free from this latter danger. They are liable to it, unless means be adopted to keep the people as a whole in immediate contact with problems of government and to give them opportunities of co-operating in some way or other in public administration. But to return to the main point. State activity in these countries seems to me due to quite other causes; on the one hand, the occasions for it are more numerous and the opportunities for it great; on the other hand, not only is there a natural predisposition in its favour, but many of the objections present in older countries are absent. But both these matters require explanation. With regard to the occasions for state action, economists, differ though they may on the question of its abstract desirability, will agree, I imagine, that in proportion as these are multiplied the tendency towards such action will increase. If we turn to what has already been said, it is clear beyond doubt that an unusual opening for such action is afforded in the circumstances enumerated. Thus the case of young industries in a new country has been admitted fairly generally to afford an argument for protection specifically different from those adduced in other instances. It is not merely the case of young industries, but, to repeat my words, of young industries in a new country. Again, the regulation of immigration is presented in a very particular form. Whatever may be thought of any particular policy of restriction—and everyone is aware that there are many and varying considerations to take into account—a country deriving a large part of its labour-supply from outside will naturally claim to exercise a supervision over the nature of that supply not less than it exerts by education and other means over the labour supplied and trained within its confines. Again, in a country developing its resources and its latent natural wealth, and under considerable and inevitable pressure to move rapidly, a large field for State action opens out. But in addition State action in the circumstances of a new country is advantageously placed, inasmuch as it takes place early, when there is little to upset, and when action of any kind and by any body is most likely to achieve really tangible results. In other words, not only are the occasions many, but the opportunity for effective action is favourable. Furthermore, the exploitation of resources, hitherto untouched, by modern and scientific methods puts a powerful instrument at the disposal of the Government which was wholly wanting in former days, while, on the other hand, the knowledge of the results which have ensued in other lands from uncontrolled individual competition indicates the direction which action should take. To this are due the attempts made in some, at least, of these countries to regulate the relations of capital and labour. Certainly, in matters of this kind, those communities have initial advantages, when measures are undertaken in a comparatively early stage of growth—before, that is, industries have assumed the intricate form usual in old lands. Nor does this exhaust the situation. A new country is inclined to novel methods of action, as is shown by the general favour with which fresh expedients are received. While a tendency like this is due in part to the innate

vigour of the people themselves, there are other causes which lend it strength: in the present instance, there is, on the one hand, the feeling that they can afford the experiment; on the other, the resolve to avoid, though the cost may be considerable and the risk great, the difficulties and dangers with which older nations are confronted. Even if the whole course is not clear, they would fain steer clear of the rocks and shoals which are charted.

Influences like these imply experimental legislation. Now, in a sense, most economic legislation is experimental; unforeseen results occur, and alteration, amendment, or repeal is required; but the extent to which it is experimental is certainly greater when we turn from the record of the past to the recent efforts of new communities. Reasons for this have been adduced, which may be briefly summarised, though in a somewhat different form. As compared with contemporary nations of a more complex type, new nations are more prone to engage in experimental legislation for three reasons: firstly, because things are simpler, and in a less highly organised society there is less prospect of interfering with a system which after all works, even if not to complete satisfaction; secondly, the consciousness of latent resources creates a greater readiness to take risks, owing to the general feeling that they can be afforded; and lastly, it is recognised that industrial civilisation carries in its train certain dangers which can be more easily anticipated than remedied. The case is a little different when the comparison is instituted with countries in the primary phase of economic life in the more remote past. Here the predominant reasons are also three. There is greater self-consciousness accompanied by a knowledge of possibilities and risks. Again, in the modern country, law is to a greater extent a conscious act and to a less extent a crystallisation of custom. Lastly, the movement of economic life and the greater rapidity of progress make other and further changes sometimes actually necessary and always less an occasion for hesitation or anxiety.

Still, a people encountering changes so rapid and sudden, and engaged in legislation experimental to such an extent, should look carefully to their armoury. Action or legislation in the economic and industrial domain, to be sound and effective, must observe certain conditions. The action of the State varies in its consequences with the relations between the people and the Government. A State which imposes law or exercises control as it were from the outside, acting autocratically or without any real identification of the private with the public will, encounters certain dangers. The essence of law lies in its ready acceptance, and this is peculiarly true of laws in the economic sphere which touch the social and home life and activities of the people. Now, any real feeling of community of interest between the people and the executive implies much more than mere popular election on however democratic a basis. It means a sense of participation in the acts of the executive, and involves a recognition of obligations as well as rights. To some extent, no doubt, this is furnished by high ideals in public life, but probably its surest basis lies in the participation by individuals in some form of public administrative action. The saying that the strength of England lay in its local institutions means even more than was intended at the time. Voluntary service in local government is to be valued not only for what it achieves, but because it quickens the interest in the State, and, if widely shared in, begets in the community an enlightened knowledge of the problems and methods of government. Again, State action, to reap a fruitful harvest, must be based on knowledge; and here I touch on a topic which deserves more time than is at my disposal—namely, the importance in such countries of economic study and the methods which this should follow. It is precisely amidst surroundings where the mass of new data is great that the need is greatest for scientific method in the examination of such data and in their comparison with the phenomena existing in other countries. Economic theory and systematic economics form part, but only part, of the necessary equipment of the modern economist, and their function is not infrequently misunderstood, and stands in need of clear definition. They indicate the relations which, so far as our present knowledge goes, exist between different classes of phenomena, and especially between these in respect of cause and effect. They place at the disposal of the student a keen instrument and a means of fine analysis which enable him to classify and co-ordinate new data, to compare these with other data, and to avoid the fallacies and misconceptions which

beset the path and invalidate the conclusions of the untrained observer. But much more is needed than these. To a knowledge of abstract things must be added acquaintance not only with economic history but also with economic phenomena as they exist and arise in the present. These furnish what may be called the content of the study of economics, and it is these which the economist has to examine and analyse. To some extent the new knowledge thus registered may modify previous generalisations. The practical bearing of such study on the problems of government and State action is obvious. But, quite apart from this immediate importance, it is a matter for regret that in a country like Australia, where there is so much economic material, comparatively little as yet has been done to treat it scientifically, and so to add to the body of organised economic knowledge.

I will take one instance. It is common knowledge that the labour legislation of Australia and New Zealand differs greatly from that attempted not only in old-established countries but in any of the other so-called new countries. We want a really scientific examination of the causes which are responsible for this difference. It is easy to make certain suggestions. Something may be due to the fact that the economic growth in Australasia is even more recent than that of Canada and the United States. Again, the manufacturing development is less advanced, and so the capitalistic element which finds its surest footing in the industrial domain is less powerful. Again, the contact with the organised industrial system of the older world is different in character from that which occurs in the case of the other countries mentioned above. Moreover the early history of Australia encouraged reliance upon the State. But suggestions like these, and others might be added to them, need careful investigation and detailed inquiry before they can be accepted as an adequate explanation of this problem; and such an investigation should be undertaken in Australia.

Hitherto I have dealt chiefly with the explanation which the previous examination of the special features apparent in new countries affords of the nature of State action in such lands.

I would turn now to an equally important question—what guidance, if any, is afforded as to particular defects which require attention or particular impulses and forces which stand in need of special encouragement? Incidentally something has been said about certain of them. The comparative weakness of custom and traditions, in one way an advantage, is from another point of view a disadvantage. The dominance of customs is harmful, not because they are customs, but because old customs are often wrong or at least inapplicable to new conditions. But custom lies at the basis of the social fabric and enables a common consciousness as to right and wrong and a community of feeling and thought which are all important in organised social life. It is possible that State action, if widely participated in and sympathised with by the people at large, may strengthen the social tie. Again, the importance of local public work by all members of the community has been emphasised: it cannot be too strongly emphasised. The besetting temptation of prosperity, and particularly of prosperity as it appears in a new country, displays itself in too great a concentration on material wealth and too exclusive a reference of everything to a material standard. It may be said that the same tendency manifests itself in the older world. That is true. On the other hand, not only are the economic circumstances fostering it much less dominant and pervading, but the social order and traditions which survive from the past provide at any rate partial corrective. As has been said before, while there is much to criticise in the notion of an aristocracy by birth or of traditional and professional standing, such distinctions counteract the influence of mere material achievement as the test of success, and indicate a vague belief, however misplaced, in some immaterial standard which at least has the merit of implying obligations as well as rights. But on what can a new country rely? On the one hand, on the recognition of the sheer excellence of manhood and character quite apart from material results; on the other hand, on a belief in education and knowledge in the wider and higher sense. This lends a peculiar importance to the encouragement of science and the development of educational ideals in a new country.

In the survey just attempted certain causes have stood out so prominently and as so influential in their results as to demand a few words of comment.

Foremost among these is contact between nations in differing stages of development. So much has been said of the economic aspects of this as it occurs between two particular types of countries that any summary would entail repetition, and repetition would be tiresome. But the subject might well be treated in much greater detail and with reference to nations and people of more kinds than these, and to the more general social and political features and results. No modern country, and in particular no new country, can escape the influence of external factors controlling or deflecting or retarding the course of its orderly evolution. These forces operate under different conditions, and the consequences which ensue vary greatly. Sometimes nations standing at almost opposite extremes are brought into close relations. The matter is further complicated when political relations exist between the countries in question. To deal much further with this matter is hardly possible at the present time. Still, two things should be added. On the one hand, nations exercising political control over other countries and races, and particularly over countries and races less advanced in general civilisation and often marked off from them by racial characteristics, bear a heavy burden of responsibility. The very relationship stimulates growth in the subject people, and yet it may well be that such growth may be so premature and so out of congruity with essential conditions as to call for measures which may retard rather than encourage it. On the other hand, it is the duty of the historian, and particularly of the historian who is an economist also, to disentangle the various influences interacting, co-operating, or conflicting in the evolution of the social and economic life of a country, and to make due allowance for forces which work obscurely and in a very subtle way. Secondly, the effects of sheer rapidity in growth must not be overlooked. The application of modern and more scientific methods to rich latent resources is sure to operate in this direction, and it may be assisted by other causes. Certain consequences are almost inevitable. Not only is the national spirit and type affected, particularly in the economic aspect, but with the denial of the time requisite for the orderly and stable evolution of custom a great call is made on the innate qualities of the race concerned if true progress is to be achieved and its fruits secured. Lastly, to a nation in the early stages of development, the spectacle and record of the experiences of other nations which have trodden the like paths, though under other conditions, mean a great deal. There is much to imitate as well as much to avoid, and, what is still more important, there is much to learn.

But whilst I say this, I would not have you think that an old country has little to learn from those which are younger. It is true that it cannot retrace its steps, and that the opportunity furnished is different in character. Still, as an economist from the older country, I would say that we expect to gain much for our guidance from the bold attempts made on this side to grapple with problems many of which, though differing in their setting, are the same in essence as those which meet us at home. Neither on one side nor the other is it a question of mere imitation. Each country has its own destiny to fulfil and must traverse its own course. The experience of others exhibits the connection between cause and effect, and those profit the most from example who discriminate wisely and best adapt its teaching to their particular conditions.

The following Papers were then read :—

1. *Town Planning in relation to the Community.*
By William R. Davidge.

Modern Legislation.—The English 'Town Planning' Act of 1909 has focussed public attention on the subject, but this Act was long preceded by the Italian, Swedish, and Prussian Town Planning Acts, all of which provide not only for town extensions and new streets being laid out on the lines prescribed by the municipal authority, but also give the authorities much greater powers of purchase or expropriation.

Buildings.—In most cases different parts of a town require special treatment, and in German town planning practice it is customary to divide the town area

into zones, each with special building regulations and restrictions as to height, number of stories, and open space.

Factory Zones.—Even under the English Act factory zones or districts may be prescribed, to which may be banished all businesses likely to cause objection by reason of smoke or noise. Such districts must necessarily be in close touch with railway or water transit, and if possible on the leeward side of the town; with the growing use of electric power, factories are becoming less objectionable, but it is still desirable to segregate them.

Land Values.—In practically all countries the constant increase in value of urban land has resulted in a corresponding increase in the height of buildings, which in turn has resulted in still further increase of value, the one reacting constantly on the other.

Limitation of Houses per Acre.—In England much is hoped from the limitation of houses per acre. The effect of such a limitation must be at least twofold: it tends first to spread the town and consequently the values over a larger area; and by restricting the use to which land is put, may to that extent decrease the value per acre of land which is already ripe for building. At the same time it will tend to give a corresponding increase of value to land farther from the town. Its effect on the already overbuilt city areas cannot fail to be beneficial, for by fixing a standard for suburban development, a high standard of amenity and a low standard of price, it will be financially impracticable to force up values in the built-up areas above a reasonable limit, and economically impossible to unduly increase the congestion of building. A reasonable return may be obtained from the land, but nothing whatever will be gained by overcrowding.

Town Extension.—The municipal authorities may by careful planning of new main thoroughfares and prescribing adequate width between buildings, not only provide new traffic arteries at a minimum of cost to themselves and the present ratepayers, but save untold expenditure in future widenings and piecemeal improvements. To secure satisfactory results, however, in this, as in other urban problems, it is essential that some one authority shall have control of the general lines of the plan.

In European countries there is everywhere evident a constant tendency to extend the boundaries of the municipalities, and such a tendency is but a natural outcome of the desire to avoid the repeated waste and overlapping of divergent controlling authorities.

Municipal Services.—With the growth of municipal services such as tramways, sewerage, water supply, gas, and electricity, the tendency towards centralisation of control becomes more marked, and there is a greater effort towards the realisation of the possibilities and ideals of the town as a whole.

Railways and Traffic Facilities.—In a plan for town extension nothing can safely be left out. Railways are as much a vital part of the plan as roads, and the position of railway stations and goods yards as important or more important than the location of shops and traffic centres. In many a town the whole development is throttled and contorted by one or more huge railway embankments laid down without regard to the growth of the town. In Germany, although railways are as autocratic as elsewhere, the need is frequently felt for revising the position of the railway stations and even the line of the railway itself, and instances of this description of complete removal of the railway have been carried out in numerous cases in connection with schemes of town extension (Frankfurt, Wiesbaden, Düsseldorf, Lübeck).

Functions of Various Classes of Traffic.—All classes of traffic—railways, electric railways, light railways, tramways, motor and heavy goods traffic—all have their proper functions, and all must have their place in the town plan. The combination of light railway and tramway (*Städtebahn*) so much used of recent years in Germany is full of possibilities, and the flexibility of the modern motor omnibus traffic must also be carefully considered.

New Streets.—In laying down the lines of new streets some form of classification of roads is desirable. In London a standard minimum of forty feet wide is adopted. In Australasia the minimum is sixty-six feet, but any such arbitrary standard must of necessity have serious limitations, and in many cases involve

heavy and unnecessary expenditure, both in construction and maintenance, to say nothing of dust and other inconveniences.

Disadvantages of Unnecessarily Wide Roads.—The classification of roads into arterial roads, secondary roads, and residential roads is commonly practised in Germany and other European countries, and nowhere better than in Germany can be seen the disadvantages of excessive road widths, with the almost natural consequence of high rents and tall tenements.

Garden Suburbs, &c.—Garden City and Garden Suburb schemes have everywhere seized upon this possibility of economising, and in such places as Hampstead and Letchworth the residential roadways are not metalled to a greater width than sixteen feet, though the distance between the houses is maintained at sixty feet or more, this leaving room for forecourt gardens or grass margins.

Access to Land.—In all problems of town development and the settlement of new towns the availability of land is of supreme importance. The questions of land values, land ownership, and land transfer are fundamentally bound up with town planning, housing, and improvement schemes.

'*Betterment.*'—No municipal authority can be expected to carry out any great scheme of improvement if there is no possibility of recoupment from the owners whose property has been improved. So long ago as 1666, in the rebuilding of London after the Great Fire, provision was made for 'betterment' charges on the owners of the property improved; and, in default of municipal ownership, some such system of recoupment is unavoidable.

'*Special Assessments.*'—In many American towns such as Kansas City, 'special assessments' for the acquisition of parks and similar purposes are in force and appear to be favourably received.

Speculation and Land Transfer.—Speculation in land is much encouraged by the facility with which land transfers can be effected, and the effect of over-speculation from this cause is apparent both in Germany and in Australasia. The effect produced is a forced and unnatural increase of prices of land until we see the curious fact that land in Berlin is valued at three or four times the value of similar land in London, and, partly in consequence, nearly one-half of the population of Berlin live in one-roomed dwellings in tall tenements crowded round one or more internal courts.

Methods of Taxation.—Methods of taxation, too, must be considered in this regard. An annual site tax on capital value leads undoubtedly to the use of land, at any rate to the extent necessary to defray the amount of the tax. In urban areas this means that fewer private open spaces will remain; in suburban areas the tendency is to put up any sort of structure that will act as a 'taxpayer.' The results in either case must be unsatisfactory, in the absence of any proper town planning scheme, defining the use to which any particular land is to be put in the general interests of the community.

Leasehold and Freehold Tenures.—The relative uses of leasehold and freehold systems of ownership have been much discussed. Leaseholds enable land to be acquired cheaply with the minimum of capital, and also have the advantage on the leases falling in of a considerable amount of property being under one control, thus enabling comprehensive improvements to be carried out, as in the case of the South London property owned by H.M. the King, the leases of which have recently fallen in, and the property has been largely reconstructed.

Municipal Ownership.—In German towns the municipality generally owns from one-third to one-half of the whole available building land, thus to some extent controlling speculation, and at the same time enabling the municipality to take the benefit of any improvement created by them. The great value of this method, however, lies in the control which it is possible for the municipality to obtain over the extension of their town. Individual freeholds, without some power of purchase or compulsory re-distribution as in the 'Lex Adickes,' will continually conflict with the interests of the community. In large estates in one ownership as at Letchworth and Hampstead, excellent results are obtained by central control, which gives benefit to the community and security to the individual.

General Conclusions.—Town planning powers would be of immense advantage to Australasia, but the special conditions call for special treatment and the

provisions of any town planning legislation must be adapted and not merely copied from European precedents.

The town planning authority should in any case possess free access to all land within their area, powers to preserve amenities, powers to reduce constructional expenses by classification of roads according to their uses, powers to vary constructional by laws, and powers to regulate the character and description of buildings and the broad lines of architectural design.

2. *The Effect of Town Planning and Good Housing Conditions on Social and Economic Well-being.* By JAMES JOHNSTON, *J.P., C.E.*

Town planning is necessary for the purposes of making a reasonable measure of health and happiness—of physical, mental, and moral health, and strength—possible in all parts of towns, of giving ready access from one district to another, under the supervision of the Local Authority, and for compelling the owners of lands to lay out and develop a district on uniform lines as distinct from each owner developing his own unit of land without regard to neighbouring estates; and not only must cities of the future be well laid out, but in the older and congested parts of our towns the slums must be cleared away and amenities provided. The Town Planning Act of 1909 gives Local Authorities power to provide open spaces and to limit the number of houses per acre, one of the best provisions in a somewhat cumbrous Act.

We have examples of the evil effect of overcrowding in many of the best planned towns, especially in Germany, where the people are crowded into tenement dwellings, entailing loss of physical and moral health, and economic loss.

The clearing away of slum property in the central area of our large towns is one of the most difficult problems to be faced, but it must be dealt with drastically, as it is of equal or even greater importance than the laying out of new areas.

The cost is the great difficulty, and under the existing law it can only be dealt with by clearing away slum dwellings in districts declared to be unhealthy areas under the Public Health Acts, and building houses on the cleared sites for the people who have been dispossessed, or by declaring the houses, separately, unfit for habitation, and compelling the owners to close, put into habitable condition, or rebuild such worn-out houses.

The dominant difficulty in housing reform is the financial one, in providing the necessary minimum of quantity and quality for the accommodation of a worker's family, on account of the limited income of the badly paid workers, and their consequent inability to pay an economic rent. The real remedy would be to give adequate remuneration to the workers, as it is now generally accepted as ethically sound that the first charge on any industry should be an adequate wage for the worker, and the adoption of this principle would render unnecessary the payment of subsidies out of the public purse for housing purposes.

The method of building houses for the workers in the future is resolving itself into a Collectivist system, as the private builder has failed to meet the demand effectively. Houses built for the sake of profit-making entirely are generally inadequate, overcrowded, mean-looking in monotonous rows, and of inferior material and workmanship. This work will have to be undertaken mainly by local authorities and public utility societies.

With facilities for obtaining money at cheap rates, a thorough organisation of the work, the more extended use of machinery, and the adoption of concrete as the principal building material, it will be possible to produce houses good in design, hygienic, and permanent in their construction, to let at an economic rent.

3. *The Economics of Town Planning.* By J. S. NETTLEFOLD, *J.P.*

Strong economic incentive is more effective for reform than official regulations. To ensure good housing, it must be profitable to the owner, and bad housing unprofitable. The same holds good with cities and their development.

The main objective of town-planners must be to provide healthy living and working conditions for all classes, especially the poor. The first necessity is

adequate supply of light and air. This means larger building sites at the old prices. There is a constant definite proportion between ground-rent and total rent. On small house property ground-rent equals one-sixth of whole. Cost of site is composed of (1) interest on capital; (2) price of land; (3) cost of development.

(1) *Interest on Capital.*—This is of prime importance. Every 1 per cent. on capital represents about 1*s.* per week on each small house: hence the necessity for cheap capital, which is unobtainable unless the town-planning scheme is commercially sound.

(2) *Price of Land.*—The supply of land available for building is severely limited by the fact that communication is not provided by public bodies except to developed areas, and builders are only willing to build near to such communications. In the vicinity of all centres there is land of low value due to lack of communication.

Town-planners must increase supply of building land by opening up cheap land and at the same time restricting building density, thereby preventing undue rises in land values. The value of land is governed by its use. Landowners should be met by allowing economical estate development and encouraging quick development, and should be given economic incentive to develop by rating land on selling price, not merely on present income. Overcrowding should be avoided by restricting building density, and, in justice to landowners, assessors must recognise that restriction of building density reduces land values. Main arteries should be cut, opening up new districts through back land, avoiding purchase of costly frontages. Sufficient width should be allowed between forecourts, but only a small width of macadam should be laid, completing with tree-planted grass margins and inexpensive pathways. Under common-sense town-planning building density is calculated per gross acre, and therefore it will not cost landowners anything to give the land for these roads; it will pay them to contribute handsomely towards the cost of construction.

(3) *Cost of Development.*—Cheap land is no good without rational development. Necessities must be provided before luxuries are considered. Light and air are more important to health, and much cheaper than magnificent architecture and extravagant engineering in the way of unnecessary sewers, kerbs, and gutters. The main objective of those primarily responsible for the 1909 Act was to reduce cost of town and estate development. Most town-planning schemes since published increase this charge instead of diminishing it. Unless care is taken, town-planning will result in worse living conditions instead of better—*vide* Paris and Berlin. Extravagant development raises rents, and makes decent living conditions economically impossible except for the favoured few. Harmony can be achieved without reckless expenditure. The City Beautiful is of no practical use unless it be also a City of Common-sense, providing healthy homes for all classes.

TUESDAY, AUGUST 18.

The following Papers were read:—

1. *The Australian Democracy and its Economic Problems.* *By* F. W. EGGLESTON.

The reputation of Australia as a scientific laboratory of social and economic experiments is to a large extent undeserved. The many departures made in Australia from the traditions of economic thought were not undertaken as part of a deliberate scientific enterprise. Nor have the results been subjected to that criticism which would satisfy an economist. In watching the development of the Australian democracy one has to realise that the process has been dominated by political considerations almost entirely. In order to better social conditions, legislators have disregarded the accepted rules of economics, and have invoked the power of the State. The basis of their policy has been the belief that the political power could provide some substitute for the forces which under ordinary circumstances go to make social conditions.

Australian democracy is thus an instinctive unrational human movement, a definite challenge to the canons of economic theory. An experience gained under such circumstances should be of considerable value, because it exhibits phenomena which might otherwise remain hidden. It shows us social institutions in a condition of disturbance, and enables us to see their working more clearly.

The characteristic note of Australian democratic development, therefore, is the attempt to secure social ends by State activity. The more typical forms of such activity are:—(1) Nationalisation. (2) Regulation of various social conditions. (3) Regulation of wages.

(1) *Nationalisation.*—Australian experience cannot be said to directly negative the warnings against State socialism. Yet the issues would not be stated in the old way. Many exceedingly valuable results attainable only by the exercise of State authority have been obtained. Much efficient work has been done by State departments, while, on the other hand, many gross failures can be recorded. A dogmatic condemnation of, or a bias against, State activity could not be maintained. Each phase must depend upon its own conditions. The tendency to monopoly in industry brings the issue of nationalisation more definitely before the public.

(2) *Regulation of Social Conditions.*—To avoid the evils of centralisation and the danger of elaborate State-directed schemes, the State will frequently, instead of assuming the management of an industry or activity, regulate certain phases of social life so as to secure ends considered desirable. In other cases it may perform an important service upon which a great many other social activities depend, or it may control a tendency which, if unchecked, would thwart the beneficial operation of the normal social forces. Thus the State insists upon conditions necessary to secure health and leisure for workers. It controls building, and formulates food standards. It investigates and guarantees the title to land. On the whole, experience in Australia is favourable to such activity. After intervention of the State, the normal social activities have readjusted themselves, and while the desired ends have been attained the vigour and well-being of the community has not been impaired.

(3) *Regulation of Wages.*—The main object of this legislation has been to secure industrial peace by fixing a mean wage between the demands of the worker and the offer of the employer. It has to a large extent failed in this object because it has been used as a means of securing higher wages. The question is whether the machinery set up has been successful in increasing real wages. The conclusion of the writer is that though the machinery is defective in many ways the real wages of the workers have been increased by it. A close examination of the economic conditions in Australia would be required to substantiate this conclusion. The enormous resources of Australia available to a small population and the relatively constant demand of labour, place Australia in a unique position. The effect of alien exclusion laws and protection, as barriers to the supply of substitutes for highly paid labour, would have to be considered. On the other hand, evidence as to the effect of high wages and liberal conditions on the efficiency of the worker and of industrial organisation are important. The progressive effect of a transference of resources from the wealthier to the poorer classes on the general efficiency and stability of the economic system is another factor in the assessment of the value of such a system. Factors on the negative side would also have to be taken into account. At the present time a notable feature of the position is that wage regulation has intensified the capitalistic organisation and assisted the tendency to monopoly and agreements fixing prices. The political effect of the rise in the cost of living is likely to be very great. The masses now believe that the capitalistic classes have turned the tables on them. Some further step by representatives of the workers to relieve the pressure of the rise in prices seems certain. Such action will be either an attempt to fix prices in monopolistic industries, or wholesale extension of the principles of Nationalisation. In unofficial sections of the masses some steps in the direction of Guild Socialism or Syndicalism is strongly advocated. From the scientific point of view, a gradual perfection of the agencies we have already installed would seem desirable. But the exigencies of politics render more drastic action certain. In such action the fundamental issues of social organisation are likely to be

raised. This movement is likely to be bitterly opposed. The more liberal elements of the middle class which have hitherto favoured the forward movement have been estranged, and a class conflict seems inevitable. There is no need, however, to anticipate serious danger from such a conflict. The social equilibrium is not likely to be disturbed more than it has been in the past. All parties are clean and honest, and much good may result from a bold facing of ultimate social issues.

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2. *On the Materials for, and the Construction of, Tables of Natality, Issue, and Orphanhood.* *By* CHAS. H. WICKENS, *A.I.A.*

This paper comprised a brief review of the statistical data available for the construction of tables of natality, issue, and orphanhood treated as functions of the age of the father or of the mother. It also outlined the methods adopted and the results obtained in using for this purpose the Census results and the Vital Statistics for the Commonwealth of Australia.

The subject is one which possesses considerable interest from the standpoint of demographic statistics, and this interest is heightened by the fact that the results so derived are essential for the solution of some of the complex problems involved in the various schemes of social insurance which have been introduced or proposed in various parts of the world. Statistics of average surviving issue of dependent age are also of importance in questions relating to such economic matters as the fixing of a minimum wage.

In a report, furnished in 1911, on the actuarial basis of a scheme of National Insurance for the United Kingdom, two eminent British actuaries, Sir G. F. Hardy and Mr. F. B. Wyatt, estimated rates of natality as a function of the age of the father from statistics of orphanhood for the Dominion of New Zealand. These data were employed, owing to the absence at the time of any suitable statistics, for the United Kingdom.

The method employed in this case was the indirect one of estimating, from the number of children living at the deaths of fathers of various ages, the number of children who had been born of fathers of various ages.

A more suitable method is the computation of the rates from statistics showing the ages of fathers at the birth of their children. Such statistics are not available in the United Kingdom, but in Australia the requisite particulars have been recorded and tabulated for many years past, and it is a matter for some surprise that this source of information has not previously been tapped for the purpose in question.

Certain other experiences have been employed in this connection, the most recent being the 1911 Census data for Camberwell, England, employed by the National Insurance Actuarial Advisory Committee. In this case again the data for determining natality rates were not the ages of the fathers and mothers at the date of birth, but were the numbers of fathers and mothers of various ages who had living with them at the date of the Census children under the age of twelve months. From these latter data the rates of natality were determined by an indirect process.

Other experiences, referred to in the course of the paper, were that of the Hearts of Oak Benefit Society in respect of lying-in claims, the experience of the Commonwealth Public Service in respect of surviving children, a similar experience for the Public Service of New South Wales, and others.

The special tables contained in the paper have been compiled from :—

(i.) the Australian statistics of nuptial births according to the ages of the fathers for the four years 1909 to 1912;

(ii.) the age results for the Australian Census of April 3, 1911;

(iii.) the mean population of Australia for the four years 1909 to 1912; and

(iv.) the rates of mortality for successive ages derived from the Australian experience for the ten years 1901 to 1910.

On the basis of these data, tables have been constructed, graduated and graphically represented showing :—

(i.) the rates of nuptial natality for successive ages of males (natality table);

(ii.) the number of nuptial children at each age surviving to males of successive ages (issue table); and

(iii.) the number of nuptial children at each age rendered orphans by the deaths of fathers of successive ages (orphanhood tables).

In the case of (i.) the working process consisted of:—

(*a*) the tabulation and graphic graduation of the data relative to births and male population;

(*b*) the computation of the rates for each age; and

(*c*) the graphic graduation of the deduced rates.

In the case of (ii.) and (iii.) the process followed was that of the synthetic construction of issue and orphanhood tables. Given the number of births arising annually per 1,000 adult males of each age, and given in addition the rate of mortality operating amongst adult males of each age and amongst children of each age, the computation of the numbers of children surviving are readily obtained, and from these the numbers of children rendered orphans by the deaths of males of successive ages.

In the computation of the issue and orphanhood rates allowance had to be made for multiple births, statistics concerning which are also available for Australia in connection with the ages of the parents. These statistics indicate that the average number of children per birth increases with the age of the father, the rate of increase diminishing with age.

Reference was made in the paper to:—

(i.) the sources of material for the purpose of similar calculations in respect of females;

(ii) to the allowances to be made in certain cases in respect of exnuptial children;

(iii.) to allowances necessary in some cases in respect of still births.

It may be noted that in the publications dealing with vital statistics which are issued by the Commonwealth Statistician, the terms 'nuptial' and 'exnuptial' are used in relation to birth as more correctly representing the fact than the more usual terms 'legitimate' and 'illegitimate.' This course has been followed in the present paper.

3. *The Present Position of the Doctrine of Interest.* *By* Professor H. O. Meredith.

The phenomenon of interest raises two distinct questions: first, why does interest exist at all? secondly, what determines its magnitude and variations? Broadly speaking, writers on the subject may be classed according as they are chiefly preoccupied with one or the other of these questions. To this is partly attributable that tendency to argument at cross purposes which characterises much of the literature of the subject.

In regard to the first question there is, however, a fundamental cleavage of opinion, though what precisely is at issue between the disputants has never been clearly stated. This paper aimed at a clear statement of the issue; it offered a brief survey and criticism of the chief doctrines of interest—viz., the Productivity, Cost, Exploitation, Agio, and Dynamic theories. In conclusion the writer's own solution was presented in outline.

4. *Economics at Oxford.* *By* Sidney Ball, *M.A.*

Introduction.—Interest and bearing of the subject.

I. Comparative neglect of economics at Oxford—signs and illustrations, and some reasons.

II. Actual but inadequate recognition of subject in examinations.

1. For a degree—(*a*) The Greats' School. (*b*) The History School. (*c*) The Pass School.

2. For the Diploma in Economics and Political Science—its scope and working.

III. Some signs of the times :—

(*a*) The course of training for Social work. (*b*) The institution of Barnett House. (*c*) The demand for a Diploma in Commerce.

IV. New influences from outside or below :—

(*a*) Ruskin College. (*b*) University tutorial classes. (*c*) Undergraduate movements—the University Fabian Society and the University Co-operative Store.

V. The situation and prospect.

The proper place of economics in the Oxford curriculum as an organic part of a school of political, social, and economic studies.—The strategic opportunity. Hopes and fears. The reform of economics at Oxford part of the wider problem of University reform.

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5. *The Statistical and Judicial Determination of the Minimum Wage in Australia.* *By* GERALD LIGHTFOOT, *M.A., F.S.S.*

The object of this paper was to examine the principles which have been evolved in the course of Australian experience in the determination of the minimum wage under the Wages Board and Arbitration Court systems, and to outline the methods adopted for investigating statistically variations in the cost and standards of living in the Commonwealth. The Wages Board system was first adopted in Victoria in 1896, and was introduced later in South Australia (1900), Queensland (1908), and Tasmania (1910). In New South Wales and Western Australia, as well as in the Commonwealth (so far as concerns 'disputes extending beyond the limits of any one State'), minimum wages are fixed under judicial systems by Industrial Arbitration Courts.

In most of the Acts under which the various systems have been established there is an absence of definition of the fundamental conception of the living wage, with the result that the basis on which the minimum should be fixed has been evolved by the tribunals themselves. In recent South Australian and Western Australian Acts, however, the minimum rate is defined and must be sufficient to secure a 'living wage' to the worker.

The work of the Wages Boards is conducted in an informal manner, and is of the nature of a round-table conference. The boards do not follow any common process in arriving at their determinations, and hence no definite principles can be found on which the minimum wage is fixed. Under the judicial method of compulsory arbitration, however, certain broad principles have been developed. In the early years of the work of the Courts the Judges apparently refrained from making any clear or definite statement as to the principles which they intended to follow, and it was not until 1905 that the duty of the Court to provide a living wage was first recognised in positive terms by Mr. Justice Heydon, President of the New South Wales State Arbitration Court.

The next important pronouncement on the subject was made in 1907 by Mr. Justice Higgins, President of the Federal Arbitration Court, who, in 'the harvester case,' first enunciated the principles which have been consistently followed by that Court. The judgment in that case has also been frequently cited and followed by State industrial tribunals.

In the course of the paper the development of the principles on which the living wages for unskilled labour is based was traced, with special reference to other controlling factors, such as the ability of an industry to bear the increased cost due to a rise in wages, inter-State competition, the deduction of an amount equivalent to the value of board and lodging, allowance for 'tips' and gratuities, the question of 'equal pay for equal work' as between the sexes, and differential rates of wages due to local differences in cost of living, climatic conditions, &c. In fixing the minimum wage for skilled workers the practice of first ascertaining the basic wage for unskilled labour and then applying the existing differences between unskilled labour and the various grades of skilled labour has been generally adopted.

During the last few years the subject of cost of living has become acute in connection with the question of the minimum wage, but owing to the absence of 'precise, cogent, detailed evidence' the President of the Federal Court for some years declined to give quantitative expression to the increased cost of

living. The basic wage in Melbourne of 7s. per diem prescribed in 1907 remained unaltered until judgment was given in 1913 in the Gas Employees' case, when evidence as to the investigations made by the Commonwealth Statistician as to cost of living was first brought before the Court, and when the basic wage was increased to 8s. In Sydney, Mr. Justice Heydon conducted an exhaustive judicial inquiry towards the end of the year 1913 with a view to furnishing an authoritative declaration as to the basic wage, and also as to ascertaining some method of raising or lowering it with the rise or fall in the cost of living. His Honour concluded that the living wage for two parents and two dependent children (under fourteen years of age) was 48s. per week.

The results of the statistician's investigations have now been adopted by industrial tribunals throughout the Commonwealth. The data are obtained mainly from two sources, viz., (*a*) householders' budgets, and (*b*) returns of retail prices and house-rents from dealers and agents in selected towns. The object of the former class of inquiries is to establish from time to time the actual expenditure on living and variations in standards, and of the latter, to furnish periodically index numbers indicating variations in the cost of living (*i.e.*, in the purchasing power of money), both in regard to point of time and as between different localities. A novel and rigorous, though simple, method of technique has been adopted and was explained in the paper.

6. *Land Taxation in Australia.* *By* G. A. McKay.

The history of land taxation in Australia was briefly narrated, and the existing systems of land taxation, Commonwealth, State, and Municipal, shortly described.

The writer pointed out that though the primary object of land taxation has been to secure revenue for the purposes of Government, there was also in some cases a secondary object, viz., to further some economic or social end of local or national advantage. The primary object, as a rule, dictated the weight of the impost; the secondary, the character of the tax, and its scope.

The main justification for taxing land, as part of a general scheme of taxation, lies in the financial needs of Commonwealth, States, and Local Governing bodies.

The Commonwealth has few sources of revenue, but great financial needs, corresponding to national burdens. It has assumed responsibility for the defence of Australia by land and sea. This has involved the provision of the beginnings of a navy, and the establishment of a scheme of universal military training.

It has accepted the obligation to provide old age and invalidity pensions, and a maternity bonus.

All these responsibilities involve large recurring expenditure, and though some payments have been made out of loan money, the fact that interest has to be paid on a growing public debt cannot be ignored.

The several State Governments are responsible for the management of all public affairs, excepting those devolving on the Commonwealth under its Constitution. The State obligations include public instruction, the maintenance of public order through the judiciary and the police, and the construction, control and management of railways, tramways, and other public works, which are outside the scope of municipal powers. Much of this expenditure is not fully reproductive, and deficiencies in revenue must be met by taxation.

Municipalities and other local authorities with similar powers undertake the construction, maintenance, and control of public works, the benefit of which is purely local.

All these authorities, Commonwealth, State, and Municipal, have independent powers of taxation, and all have recourse to land as one of the main sources of revenue.

The economic and social reasons for land taxation are included in two main branches—one the desire to make a breach in land monopoly, the other to ensure that land, the foundation of most national assets, is put to its best use from a national point of view.

The history of land monopoly was traced to early legislative and administra-

tive errors or omissions, and to the absence of a proper classification of land, with separation of pastoral and agricultural interests.

The perpetuation of the large estate once accumulated is assisted by family sentiment and the innate conservatism of the average landowner.

The national desire that land should be used for its best purpose is kept alive by the agitation of men who desire to obtain land for agricultural purposes, but are prevented by the existing pastoral occupation. There is also a constantly increasing antagonism in the popular mind against those who misuse or neglect the opportunities afforded by the ownership of land.

The experiments on hybridisation of wheat which resulted in the invention of varieties capable of withstanding some degree of drought have brought immense additional rust-proof areas of land into the agricultural domain, and incidentally brought the owners of these lands within the scope of the attack directed against land monopolists and those who do not use their lands to the best advantage.

The general policy of taxing land was analysed with special reference to the paramount need of encouraging land settlement, and the possible contingency that cumulative imposts of this nature may tend to create the impression that such enterprises are unremunerative.

The independent action of Commonwealth, State, and Municipal agencies in this connection accentuates the danger, as each pursues its taxing scheme with a view to its own financial needs, and possibly without paying any regard to the gravity of the tax imposed by other agencies. The possibility of substituting one taxing and valuing agency for the existing agencies is discussed, and a scheme suggested which should minimise cost and secure greater consistency and efficiency.

The Federal scheme of taxation was described with special reference to the policy of exemption from tax in certain cases; the graduation of tax; the taxation of secondary interests, such as land represented by company shares; and the taxation of absentees on the higher scale.

The relation of the taxing scheme to certain forms of land tenure was considered. The differentiation in treatment in favour of landholders in different States holding under almost similar titles was shortly described.

The general effects of the several land tax systems in the direction of stimulating settlement and bringing about a more effective treatment and greater productiveness of land was illustrated by reference to available statistics.

WEDNESDAY, AUGUST 19.

The following Papers were read:—

1. *On Certain Characteristics of Manufacturing Industry in Australia.* *By* G. H. Knibbs, *C.M.G., F.S.S.*

In this paper characteristics of manufacturing industry in Australia are quantitatively analysed from the data covering all such industries in that country. The basic principle of the analysis was to form such groups as would disclose the relationship of the elements compared, the groups being large enough to minimise merely accidental influences. In doing this the arbitrary magnitudes of individual businesses and the absolute cost of the material used were eliminated from the problem by restricting the analysis to capital invested per employé, the added value per employé, horse power per employé, and so on.

It is shown *a priori* that certain characteristics of the relations, for example, of 'added value' and wages, both per employé, to capital invested per employé are likely to obtain. These may be expressed by an equation of the form $y = Ae^{-nx-p}$.

The personal and local factors mark this in small groupings, and even in groupings for individual industries. Certain large groupings seem to show that these *a priori* deductions do characterise industry in the aggregate. In the endeavour to secure from industry the highest wages possible 'added value'

measures the importance of industry to the employé, but not to the proprietor or proprietors. The proper reduction of this covers interest charges and general risks of industry, and is often misunderstood. This is scarcely less important in co-operative industries in a country in touch with the world. This fact is probably not adequately appreciated.

The value of wages, paid in money, depends upon the purchasing power of wages, *i.e.*, upon 'effective' wages; *i.e.*, their value reduced to some common datum, which is best measured by the cost of a 'composite unit.' In Australia wages in some industries have been determined on the principle that they should be equated to the changing prices of commodities, or 'cost of living.' In principle, to be equitable, this must be general. But the direct effect will be to increase the price of commodities, and thus to force them continually upwards, and thus to defeat itself. The tendency may be exhibited by computing the consequence on the assumption of an automatic and instantaneous adjustment. The effect is startling, and though perhaps of less consequence in a self-contained country, is of a far-reaching significance to a country in competition with the rest of the world. The complete solution of the problem is very difficult even for a self-contained country.

Economic investigations to be of high value must be quantitative, and only in this way can either their scientific or sociological value be advanced.

2. *Estimate of the Private Wealth of a Community and the Measure of its Uncertainty.* By G. H. Knibbs, *C.M.G.*, *F.S.S.*

It is very doubtful whether the private wealth of a community can be ascertained with any degree of accuracy even by means of an elaborate census of wealth, and even then comparisons at different dates would require to be used with caution. A rough estimate, made from a limited parcel, by means of which the average per individual is ascertained, to be applied to the entire population, would be subject to still larger uncertainty.

Probably, for large averages, and in any one community, income and accumulated wealth are fairly closely related, and deductions may also be made on that basis. Such methods are subject, however, to obvious and grave limitations.

Since death incidentally involves estimates of value of a deceased's estate for the purposes of probate duty, such estimates, which also are subject to grave defects, have been applied to determine the private wealth of the living, on the assumption that, with suitable precautions, the deceased group may be taken to represent the entire community. This is essentially a 'parcel' method.

The reliability of an estimate necessarily depends on the factor applied to the value of the estates of deceased persons to get the value of all estates. This, however, is subject to large accidental variations, and, moreover, is not constant, since it depends on the death-rate, itself a changing quantity.

The solution reaches its highest value when age-groups are independently treated and its inherent limitations are also best disclosed thereby. There are characteristic differences between the wealth of the sexes and its variation with age, and these affect all deductions.

Deductions from income returns may be related by a suitable investigation with those from probate returns. In this connection it is important not to rely on Pareto's so-called law. The apparent rough validity of this law merely depends on the fact that a considerable stretch of either branch of any unimodal frequency-curve can be represented by a general parabola or hyperbola $y=Ax^{\pm n}$ where n may have other than integral values. It also masks its defects by dealing with aggregates, since the integral of the above expression is also a general parabola whose index is $n+1$, and as a matter of fact is disposed of by a study of Prussian income returns.

Probate returns can hardly be regarded as normal estimates of value, and expert estimates vary enormously according as to whether they tend to represent cost-price, fair market value, or value at forced sale. Individual estimates made at leisure differ enormously, and may be either sanguine or conservative estimates, while the differences between esteem, utility, and market values are very great.

The problem cannot be made absolutely definite, even by a Census of Wealth,

and is only fairly so when the fluctuating value of the money-commodity (gold) in comparison with commodities generally is taken into account. The expression of estimates of this character to a high order of precision is of course misleading, and, owing to the uncertainties in the method, it is of limited value for estimates of material progress.

The following Paper was not read, but was printed in full and distributed to members of the Section:—

Australian Defence.

By Senator the Hon. G. F. Pearce, *Ex-Minister for Defence.*

This subject falls naturally under two main aspects, Imperial and Local, with technical divisions, Naval and Military.

Australia is affected by, and interested in, the defence schemes of the Empire, and every phase of the question must be considered from the point of view of the effectiveness of those schemes.

The Imperial Conference in 1911 made full provision for the co-ordination of Australian Naval Defence with the Admiralty plans. Theoretically it is argued that any system of divided control is unsound, while, on the other hand, if local control is given up, local autonomy is surrendered. The latter course has no chance of being adopted in Australia, the people of the Commonwealth considering national sentiment more powerful than written agreements. A navy within a navy is a logical outcome of a nation within a nation. The naval subsidy was never a popular arrangement in Australia. The Dreadnought scare solidified opinion in favour of an Australian owned and controlled navy. The expenditure on local naval defence has evoked no protest. British interests in the Pacific cannot be left to arbitrament of European nations or to the friendly keeping of an Asiatic ally. The provision of a fleet unit has made available to the Admiralty ships and personnel previously locked up in Australian waters. The Japanese alliance is only for a definite term, and at its conclusion a fleet could not be brought into being in a moment. Even a weak navy guarantees that there can be no land invasion until it is destroyed or neutralised, thus giving breathing-time. The question of so directing the naval policy of the Dominions as to afford methods of effective combination and co-operation in time of war was decided for in the Naval Agreement of 1911.

With reference to Military Defence, Australia has adopted the principle of compulsory universal military training. Persons enrolled under the Defence Act cannot be called on for service outside Australia. The obligation for universal service in time of war was always a feature of Australian Defence Acts. The claim for universal training is based on the fact that all are entitled to vote, and as the result of a vote may involve Australia in war, all should therefore bear the responsibility. Voluntary service is unfair, and is found by experience to be ineffective. The vastness of the country demands a numerically strong force. All law is based upon compulsion and to some extent trenches on the liberties of the people. The distance from Europe makes it unlikely that Australia can take any effective part in European conflicts. Apart from its purely military aspect, the military scheme provides for the physical training of the youth of the Commonwealth and for universal medical inspection. Training from youth upwards instils discipline into the mind while still receptive, and is a substitute for conscription of adults and for the barrack life inseparable from a permanent army. Medical examinations take place at the ages of twelve, fourteen, and eighteen; the particulars are entered on cards and tabulated, thus providing data of very great value to medical scientists. These examinations at the ages specified enable physical defects to be revealed, so that remedial action may be taken at such time as to ensure the future life of the youth being useful and healthy. The obligation of universal training will be an effective check on military jingoism by creating a sounder opinion on the realities of war.

The possession of a navy makes it essential that naval bases and dockyards should be provided, and steps are being taken for such provision. The distance of Australia from Great Britain as a base of supplies renders it necessary to make local provision for munitions of war, and to this end various departmental

factories have been established. The magnitude of Australia's maritime trade is a further justification for defence expenditure, apart from the fact that her population and principal cities are chiefly confined to the sea-board and so render her particularly vulnerable to attack.

The most important events in the development of the scheme since its inception are here outlined :—

In 1901 the Deakin Government sent a representative to the Imperial Defence Conference in London, at which arrangements were concluded for the establishment of a Pacific Fleet, to which the United Kingdom, Canada, New Zealand, and Australia were to contribute fleet units. Subsequently, the Federal Government asked the Admiralty to invite tenders for battle-cruisers.

In 1908-9 the Fisher Government gave orders for three torpedo destroyers.

In May 1910 the Federal Government invited the Admiralty to send out an expert naval officer to formulate a scheme of naval defence. As a result of this, Admiral Sir Reginald Henderson arrived in September of that year and presented his report in March 1911.

In 1910 the Fisher Government undertook to provide the remainder of the fleet unit, and at the present time, with the exception of one cruiser and three destroyers, which are in course of construction at the Commonwealth Dockyards in Sydney, the Australian fleet unit is in commission.

With regard to the military scheme, the Deakin Government in 1909 invited Lord Kitchener to visit Australia and propound a scheme of Military Defence under the Defence Act. Lord Kitchener's scheme is based on territorial organisation.

In 1910 the Fisher Government extended the provisions of the Defence Act to provide for adult training.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *Sociological Aspects of Town Planning.* *By* J. D. FITZGERALD.

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2. *The Health Aspect of Town Planning.* *By* JOHN ROBERTSON, *M.D., B.Sc.*

Town planning in England, as we now know it, was originated to prevent the evils which have arisen in the larger towns due to crowding on space, and the baneful influences arising from permitting factories and works of all kinds being interlarded between dwelling houses, in such a way as to make these dwellings dull and gloomy from the smoke laden air, and dirty from the soot which gains access to the interiors. In most of these large English towns adequate space for the healthy recreation of the dwellers in the central areas was not provided, and in most instances no attention was paid to the amenities of the district, except in a few instances where great natural features existed.

It is very important that density of population should be limited to enable houses to be separated from each other: (1) to allow of sunlight gaining access to each inhabited room, (2) to permit of a current of air at all times round the house, (3) to allow of privacy in the dwelling without the necessity of covering windows completely with curtains, which have been proved to shut out up to ninety-seven per cent. of the actinic power of the sun.

Artisan areas arranged on town-planning lines are difficult to compare with good areas on old lines as regards their health statistics. If one makes all allowance for selection and class, there still remains so great a difference between the statistics of the new and the old conditions as to leave no doubt that in actual practice town planning is one of the greatest advances which have been made in recent times for the benefit of the public health.

3. *The Planning of Sydney—Past, Present, and Future.* *By* JOHN SULMAN, *F.R.I.B.A.*

Captain Phillip landed on January 26, 1788, in Sydney Cove, now the Circular Quay, and formed the first settlement in Australia. In his earliest report he refers to the large trees covering the site, the rocky points, and deep water close in shore. His plan shows a street 200 feet wide, and allotments 60 feet by 150 feet for each house, but it would not have been a workable one for a city as the outlets were not studied.

The actual plan followed the lines of the original barracks on the Tank Stream, and the track to the surrounding country (now George Street) later on developed by parallel and cross streets.

Up till 1809 the growth was more or less haphazard, but Governor Macquarie then initiated many improvements, aligning the streets to 50 feet wide, abolishing nuisances on the Tank Stream, the only water supply, and reserving Hyde Park in perpetuity for the recreation and amusement of the people and exercising the troops.

Sir Thomas Mitchell, the Surveyor-General, whose reports from 1827 to 1855 are available, did much to improve Sydney, and, had his suggestions been adopted, much excellent town planning would have been effected. He was responsible for the reservation of Cook Park, the preservation of native timbers, and the laying out of well-graded roads into the surrounding country. His many recommendations include a contour road which would have obviated the steep William Street hill, the artistic treatment of Church Hill by a crescent and obelisk and radial planning leading up to a dignified entrance to Government House. He advocated wider streets, and obtained an order to align to 100 feet if possible, and proposed an excellent lay out for North Sydney around the present Crow's Nest. He also effected many sanitary reforms for traffic purposes, and suggested small squares at street crossings instead of rounding off corners.

Outside the city, however, speculators cut up land into small allotments with frontages to 20-feet lanes, and so laid the foundations of the slums of to-day. Later on, the outer suburbs were mostly planned with 40-feet roads, but cross communication between suburbs was entirely neglected. Mr. (afterwards Sir) George Reid passed an Act to compel a minimum width of 66 feet for all roads, which is still in force and has its defects as well as advantages.

For twenty-five years the author has been advocating town planning, and in 1908 this resulted in the appointment of a Royal Commission to consider the improvement of Sydney, and some of the recommendations thereof have been carried out, such as the widening of Oxford Street, the formation of Wentworth Avenue, and a new road from Woolloomooloo, and the resumption of one or two slum areas. But these improvements have been confined to the city proper.

In 1913 the Greater Sydney Royal Commission recommended a scheme by which in time all the numerous suburban councils and areas would be absorbed, and power given to a unified council to town plan on a comprehensive scale, but legislative sanction thereto has yet to be obtained.

As regards the future development of Sydney the most urgent problems appear to me to be as follows:—

1. The provision of an underground city railway with branches to the suburbs.
2. The building of the North Shore Bridge or tunnels or both.
3. A bridge or tunnel to Balmain.
4. The widening of the main city streets to at least 100 feet to provide not only for increasing surface traffic but for light and air to the buildings 150 feet high permitted by Act of Parliament.
5. The formation of main north and south and east and west avenues.
6. A proper convenient and beautiful land entrance to the city at the railway station, and a water entrance at Circular Quay.
7. The setting aside of an industrial area with all facilities in the way of railway communication and water frontages, so that manufacturing may be carried on to the best advantage.

8. The planning of a series of main radial and circumferential roads, 100 to 200 feet in width, to link up all parts both of the Sydney of to day and the greater Sydney of the future, and the planting thereof with trees.

9. The provision of playgrounds over the whole area not more than half a mile apart, and parks or reserves not more than a mile apart.

10. The reservation wherever possible of belts of open land in perpetuity between suburb and suburb, so that the greater Sydney of the future may consist of the city proper and a number of subordinate but economically self-contained and independent centres, and thus avoid the formation of a single large congested city area.

11. The resumption of the foreshores of the harbour wherever possible, the allotting of specific portions for trade with adequate rail communication thereto, and the beautifying of the remainder for the use and pleasure of the public.

12. The duplication of the water supply, for at present everything depends on one line of pipes.

13. The passing of a Town Planning Act similar to the English one of 1909 to enable many of the above suggestions to be carried out.

There are many other improvements that could be suggested, but if the above are effected Sydney would be a city very different from what it is, and worthy to rank amongst its peers not only in Australia but in the greater world beyond the seas.

In conclusion the author expressed his hearty acknowledgments of the valuable aid given him in his researches, and for the permission to photograph rare and valuable maps and plans by the authorities of the Lands Department, the Mitchell Library, the Municipal Library, the City Surveyor, and others.

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4. *Town Planning in relation to Housing and Health.*

By William R. Davidge.

The present-day evils of cities are largely of modern growth and due to the rapid industrial expansion of the nineteenth century. Slums exist in Australasia as in Europe, though not at present to so marked a degree.

The incidence of bad housing, wages, land values, and transit should all be considered. The evils of uncontrolled suburban development are everywhere apparent, and the effect of existing by-laws and legislation is in many cases but to increase the cost of living for the masses.

Cheap housing depends primarily on cheap land and cheap transit. Cottages compete favourably with block dwellings from the point of view of commercial and family life. Economic rent is, however, strictly limited, and capital expenditure on roadmaking and constructional works should be reduced to the absolute minimum. Prices of building materials are advancing, and the cheap cottage becoming increasingly difficult.

Garden Cities and Garden Suburbs seek to amalgamate the forces of industrial progress with those of health and social welfare. In a system of garden suburbs linked to a central business community the advantages of both town and country may be secured.

The effect of public open space and parklands is under present conditions to increase the value of land in the immediate vicinity, and thus in some cases to render still more difficult the housing of the poorest part of the community. The Garden City ideal is to bring every part of the community in close touch with the open country. The belt of agricultural land has many economic possibilities, apart from its use for allotments, recreation grounds, and similar purposes. The pioneer settlements in both Australia and New Zealand were in many ways practical forerunners of the Garden City ideal.

The individual owner under a properly considered town-planning proposal has perfect security as to the development of adjoining properties, and the growth of a proper civic spirit can be encouraged. Co-partnership in housing, combined with the limitation of dividends, has achieved great success in the development of such communities, and by the aid of State loans there are many further possibilities of co-operation between State, municipality, and individual.

Greater still is the possibility of bringing existing towns into conformity with Garden City principles. Legislation is necessary to provide for the town planning of future suburbs and the improvement of existing towns.

MONDAY, AUGUST 24.

The following Papers were read :—

1. *The Influence of Distribution on Production.* *By* Professor R. F. Irvine, *M.A.*

The object of this paper was to suggest a line of inquiry rather than to attempt a complete demonstration.

1. Owing partly to the fact that economists have often failed to give due weight to social reactions and interactions, the tendency has been to regard Distribution as a result, and as a result only. The social income is always a function of production; the amount which is actually distributed depends entirely upon the efficiency of the Productive system.

2. There was no hint in the 'Classical' Political Economy that an improvement in Distribution—by which is meant an approach to greater equality—might lead to greater social well-being than actual increase of the income. Professor Pigou has recently shown, and most economists admit the validity of his reasoning, that 'so long as the dividend as a whole is not diminished, a gain to the poor, achieved through more equal distribution, means an addition to economic welfare.' This is the first step in the line of argument suggested.

3. The next step is to show that at almost every stage of industrial evolution there has existed a fund which might have been redistributed without in any way impairing the efficiency of production.

4. Except in so far as they have recognised the 'economy of high wages' or expressed, in stray passages, the belief that a more equal distribution would be a gain to production efficiency, economists have made no formal attempt to examine the further possibility that an improvement in distribution might lead to an increase in the dividend itself. It was the aim of this paper to suggest that carefully graduated approaches to greater equality will in the long run result in (1) a change in the direction of industry, and (2) an increase in the volume of production.

5. The first point needs little elaboration. If the incomes of the wealthier classes, or, rather, the amounts they normally expend on consumption, were reduced by a given amount, and this amount distributed among the poorer members of the community, it is evident there would be, in consequence, (*a*) a diminished production of some of the luxuries of the rich, and (*b*) an increased production of the necessaries, comforts, and luxuries desired by the poorer classes. No matter how slight the increase of 'purchasing power' thus diffused among the latter, it will effect a change in the direction of industry. Society will begin to organise itself in a new way, better calculated to promote the general welfare. Fewer workers and less capital will be engaged in the service of wasteful ostentation and in the provision of luxuries which tend normally to diminish productivity.

6. But this diffusion of purchasing power cannot stop at a mere diversion of industry. Given time, it will exercise a powerful stimulus on the whole productive system. The new force of demand, coming as it does from the millions, will be persistent and reliable, and will set in motion forces which tend to progressive improvements in machinery, in processes, in organisation, and finally to reduced costs. It will tend also to increase the supply of ability by bringing new classes to a higher plane of existence.

7. There are, of course, limitations, but they are all capable of expansion. They are :—

(*a*) Available natural resources.

(*b*) The capacity of all classes to understand the situation and to co-operate to make the most of opportunities.

(c) The recognition that if production is to be efficient no factor can safely be deprived of the stimulus necessary to evoke its fullest service.

(d) The capacity of society to secure control of monopoly, and particularly monopoly price-making.

8. Illustration of the principle from a consideration of transitions in industrial history.

9. Its relation to the question of a national minimum wage and to Wages Board awards.

2. *Some Thoughts on Economic Evolution.* *By* Professor H. O. Meredith.

Economic evolution is due partly to changes which are external to the individual and are largely non-economic in their own nature. It is part of the business of the economist to study these changes because they are in themselves indubitably economic phenomena; but inasmuch as some at least of their causes belong to the data of other sciences, they illustrate the difficulty of drawing a precise line between the economic and other fields of study.

Economic evolution is also partly due to a kind of activity which is both individual and in a strict sense economic. This activity may be called 'creative enterprise': it offers close analogies to the activities which chiefly determine progress on other sides of human life. The working of this force has been somewhat neglected or disguised in the development of economic science: mainly because it lends itself so little to scientific measurement or analysis. This neglect is of small moment in statical studies, since the force plays no part in relation to statical phenomena. Its tacit exclusion from dynamic hypotheses is a more serious matter: a study of dynamic phenomena which neglects one of their main determinants is necessarily unsatisfactory.

3. *The Rate of Interest in Australia.* *By* A. Duckworth, *F.R.Econ.S.*

The circumstances which regulate the rate of interest have by many writers been treated in a somewhat loose way. The rate of interest on new investments of capital is that which is of chief importance. Some writers regard the real cause of interest as monopoly, and without private ownership of land, interest never would have existed, whilst compound interest is asserted to be wrong in theory. Such views need to be considered in any consideration of the subject. As regards Australia, borrowed capital has been largely availed of in the development of the country. The public debt of the Commonwealth exceeds three hundred millions, but is largely represented by productive assets such as railways, &c. At times the internal market has been denuded of capital by Governments competing with private borrowers. The State, by means of the savings banks, has been able to attract savings of the community to the extent of about seventy millions. To stop the supply of Government loans would mean disturbance of trade and stoppage of public works already in progress. Australasian Government loans issued in London falling due up to 1920 exceed fifty million pounds. The importance of renewals on good terms is obvious. Next to Governments, the cheque-paying banks control large sums on deposit. Average deposits, one hundred and one millions in 1893, in 1912 were one hundred and forty-eight and a half million pounds. The fire and life insurance offices form another financial factor with funds exceeding sixty million pounds and possibly becoming a dominating factor in the local markets. As they do not trade on borrowed money, and need not realise for long periods, they may impartially select both borrower and security. In England and America their operations are much more extensive. On the whole, Australia now owes overseas less than she did ten years ago. The security of the principal of her debt is of course undoubted, being based on public credit, backed by rates and taxes, and by the revenue from public undertakings and private enterprises. With a high rate of profit, such as is usually attendant upon the successful and rapid development of new countries, it follows that the rate of interest in Australia must continue for long enough to be higher

than in older settled communities. The taking of interest presents itself in a different aspect now from that of the Middle Ages, when the actual prohibitions of the Church were constantly evaded by ingenious legal fictions. Supposing farmers in Australia to obtain a profit of twenty per cent. in comparison with farmers in England able only to obtain, say, a profit of ten per cent., the Australian farmers can obviously afford to pay a higher rate of interest for the use of the necessary capital. The rate of profit determines in general both the maximum and the minimum of interest. If any monetary combination were to be proposed so as to secure any monopoly of capital—a money trust—Government moneys and funds of insurance and other financial corporations would be opposing factors. The world's need for capital leads to higher prices for capital. Australia is necessarily affected by the outlook, but unforeseen factors may modify the most careful attempts to forecast the future of the rate of interest in Australia.

TUESDAY, AUGUST 25.

The following Papers and Report were read :—

1. *The Economics of Marine Fuel. By* Professor A. W. KIRKALDY.

The utility of the steamer was limited until :—

(1) Coaling-stations were available at convenient distances on ocean routes.

(2) Improvements were effected in the marine engine and boiler which resulted in a moderate consumption of fuel. Of these :—

(1) was effected under British stimulus. First the mail routes were equipped with coaling-stations; then, when these were prepared to supply fuel to all comers, the cargo-steamer became a possible competitor with the sailing-ship. Gradually all routes where steamers can operate have been provided with coaling-stations. In the first instance these coaling-stations were supplied with English coal.

The mail and passenger services admitted of heavy expenditure which cargo-steamers competing with sailing-ships, and without subsidies, could not have faced.

(2) The second limitation to the steamer was met by the invention of the compound engine in the year 1858. This invention opened up the possibility of steamers competing with sailing-ships for world-commerce. In 1881 the triple-expansion engine and subsequent improvements—quadruple expansion, twin and quadruple screws, the geared-turbine and the internal-combustion engines—have completed the victory of mechanical propulsion over sails.

At the present moment the attention of managers of cargo-steamers is focussed on the rivalry between the geared-turbine engine and the internal-combustion engine.

Coaling-Stations, their Equipment and Supply.

(1) At first they were English both in organisation and in supply of fuel.

(2) Gradually came the opening up of other sources of supply of fuel for shipping purposes :—

Australia, India, Japan, the United States of America, Germany, South Africa, etc.

(3) Hence a restriction of the area that can be economically supplied from English collieries. The area has been reduced, but there has developed an increased demand for English coal in the smaller area.

(4) The importance of coal freight to ocean commerce :—

- (*a*) It equalises the bulk of imports and exports in United Kingdom trade.
- (*b*) The Suez route supplied mainly with British coal.
- (*c*) The Panama route may be supplied with American coal.
- (*d*) What this competition may entail.

The Economics of Oil Fuel.

Coal in its crude state can only be utilised for steam raising purposes in a furnace, hence :

(1) the necessity of large coal-bunker space in steamers.

(2) coal being comparatively difficult to handle and stow on board ship has to be placed near the boilers.

(3) the bunkers occupy some of the best cargo space.

(4) these very considerably affect cargo carrying capacity, and so the economical working of the ship.

Oil can be utilised in either a furnace or in a cylinder *i.e.*, may be used for either reciprocating or internal-combustion engines. This has several important economic effects :—

(A) Where used as fuel for reciprocating engines :—

(i.) one ton of oil will do the work of $1\frac{1}{2}$ ton of coal.

(ii.) bunker space is greatly reduced because : —

(*a*) less fuel need be carried.

(*b*) the oil can be pumped into any out-of-the-way space in the ship; thus spaces into which neither coal nor cargo could be stowed can be utilised.

(*c*) oil can be carried in the ballast tanks.

(iii.) economy in transporting, handling, storing, and stowing.

(iv.) less labour is required :—

(*a*) only about two-thirds the number of firemen need be carried.

(*b*) no trimmers are required—these two items reduce the wages bill by about 33 per cent.

(*c*) the food bill is reduced by a like amount.

(*d*) less accommodation is required for engine-room staff.

The saving in wages, food, and cost of fuel in a recent trial of oil against coal, tried on the same vessel, showed an advantage in favour of oil of no less than 34*l.* on one day's steaming on a steamer of 3,800 tons.

(B) In the case of internal combustion engines :—

(i.) one ton of oil will do the work of four tons used for heating boilers.

(ii.) there is considerable reduction of bunker space over oil-consuming reciprocating engines, and a very much greater saving of space over coal-driven engines.

(iii.) there is the economy in handling, transporting, storing, and stowing already noticed.

(iv.) effects on labour :—

(*a*) less labour is required; here there is an economy over engines driven by oil fuel, as neither firemen nor trimmers are required.

(*b*) the number of the other members of the engine-room staff can be reduced.

(*c*) *social effects*—these are important. The coaling and stoking of steamers have a brutalising effect on the men employed. This is a blot on steamship service. The greater cleanliness and the better conditions of work connected with the use of oil as fuel will tend to raise the standard of one class of shipping labour, and will eliminate altogether a type of work which is inherently brutalising.

(v.) the engines occupy less space and there are no boilers. Hence saving in space includes :—

(*a*) bunkers.

(*b*) engine and boiler-room space.

(*c*) sleeping and other accommodation for the staff.

(C) Sources of supply :—

These are now known to be far greater than was once thought. They include :—

(I.) Oil in the fluid state.

(II.) Various shales, coal, etc., whence oil can be distilled.

As to (I.) of areas already supplying oil there is Eastern Europe, and apparently a vast workable area running thence throughout Asia to the Pacific.

The known resources of North and South America are very great, and in Canada, the West Indies, and in many parts of South America there is promise of equally rich supplies yet to be tapped.

As to (II.) the various shale areas have hitherto scarcely been worked. Scotland is rich in shales, and, only to mention newly discovered fields, there are rich shale areas in Australia, New Zealand, and South Africa. In nearly every land area there exist shales, coal of various qualities, or clays whence oils can be distilled.

So far as coal is concerned, to utilise it in this way would result in economising coal resources, and much that is now wasted would be utilised.

Some distilled oil contains impurities, but this drawback must sooner or later be overcome.

(D) Price of oil :—

This at present is a problem, but some experts are sanguine that when the oil industry is efficiently organised the great supply available will sell at a moderate price.

It has been estimated that, given an efficient internal-combustion engine, oil at even 6*l.* a ton would show a saving over coal-driven reciprocating engines, at current coal prices.

(E) The need of the moment is that the Empire should train men to work its resources, which promise to be ample for all purposes. At present oil experts are either Americans or natives of Eastern Europe. Hence the British industry is, to some extent, in the hands of those possibly having antagonistic interests.

Only one University in the United Kingdom has organised a course of training for oil-mining. Every modern University in the Empire should supply this training.

In conclusion, this is not merely a matter of international commercial competition. It is a far wider question on which the healthy social development of the Empire may depend. Sources of power must be developed to the utmost in the interests not only of the trade and commerce of the Empire, but of the world as a whole. The possibility of the British Empire taking a lower place, when it contains resources which should enable it to lead the world, would result in a set-back to civilisation.

2. *The Selection of Employment for Juveniles.*
By Mrs. C. M. Meredith.

The selection of employment for juveniles has only recently become a matter for State action in England. Attention has been directed to it primarily as one side of the general movement for dealing with unemployment, and as a means of lessening the number of 'blind alley' occupations adopted.

In this paper I propose to discuss two questions :—

1. The considerations of economic importance to the community which should be kept in view in selecting employment for a boy or girl leaving school at fourteen.

2. The information at present available to aid in such selection and in what ways this requires amplification.

1. From the economic point of view the boy's future work as an adult citizen is more important than his present capacity for work; hence an employment must be regarded as 'bad' not only (*a*) if it tends to produce deterioration (whether physical, mental, or moral) in the worker, but also (*b*) if, although healthy and desirable in itself, it prevents him from getting the training required to enable him to earn an adequate wage when he is grown up.

It is also necessary to consider how far a boy's success is dependent on the nature of the occupation he selects and how far it is chiefly a matter of character and 'general' intelligence. On this point different opinions are held, and some questions await further investigation, notably that of the connection between enjoyment of work and efficiency.

2. We require to know (*a*) the conditions prevailing in the various employments and the qualities demanded in those who enter them; (*b*) the qualities

and tastes of the boy seeking employment. On the former point a considerable body of evidence is readily available, and more can be obtained without serious difficulty. The second point presents many more obstacles. The chief sources of information are: (1) The boy himself, (2) his parents, (3) other persons interested in him, such as members of the school care committee, (4) the reports from his school.

Of these sources of information the possibilities of No. 4 have as yet hardly been recognised in England, with the exception of the reports relating to health. The school reports on other matters could be extended, and could be based on evidence collected, by experimental or other means, directly with a view to finding the special qualities whose presence or absence is important as a guide to the selection of work.

3. *Interim Report on the Question of Fatigue from the Economic Standpoint.*—See Reports, p. 175.

4. *Industrial Arbitration in relation to Socialism.* *By* F. A. A. Russell, *M.A.*

The system of Industrial Arbitration commenced in New South Wales by the Act of 1901 (Mr. Wise's Act), the Board system introduced by the Act of 1908 (Mr. Wade's Act), the rapid creation of Industrial Boards dealing with nearly all industries in Sydney and in many country parts. This Act becomes a means of rapid introduction of State regulation of labour both as to wages and other industrial conditions; the system of the Wade Act continued and enlarged by the Act of 1912 (Mr. Beeby's Act). So that for most practical purposes we may regard the operation of Industrial Arbitration from 1908 to the present moment as the working of a continuous system, subject mainly to some difference of administration.

A. First main result of the 1908 Act:—(1) The spread of unionism is assisted and accelerated both in the country and in the metropolis in industries where it had before very little foothold, and (2) the consolidation of unionism where it already obtained. The 1912 Act helps on completion of this process.

B. Further results:—It is my opinion, and I shall attempt to show, that the Wade Act introduced a larger measure of Industrial Socialism than the leaders of the party which passed it realised at the time. Suggest there are few people who realise now the changes capable of being achieved in the industrial structure of society, and which are in part occurring at the present moment, under these and similar Acts.

Some description of the more important controversies which have arisen in the working out of the system and some understanding of the stages reached to date on the lines of these controversies required to illustrate these views.

(1) *Preference to Unionists* tends to drive all men into Unions; the mild form in which it is allowed in New South Wales tends to mitigate personal hardships in transition stage; its chief value to the Unions lies in fact of further recognition, plus an organising value—not directly injurious to employers (unless the whole system is injurious)—a part of a Socialist movement, but right in kind. Combat the idea that personal freedom is really menaced by unionism.

(2) The lines of development of unionism, and of the jurisdictions dealing with industrial matters. The Crafts *v.* Industries argument in relation to the principles on which Unions are constituted, and jurisdictions dealing with them marked out. Earliest administration of the Beeby Act represents high-water mark for Craft Unionism in New South Wales. Both the Craft and the Industries Union are necessary. The problem of adjusting their rights. Opinion that Unions constituted on the Industry basis are the more suited to modern developments, and the mere force of circumstances is favouring this principle of constitution, while the Crafts Unions act as a conservative check. The Industries Union may favour Syndicalist action, but any danger in that should be averted by means other than an attempt to favour the Craft Union.

(3) Claims for flat rates of wages—reasons advanced—instances of attainment and instances of increasing diversity of rates—general tendency.

C. *Rising Wages.*—How far the Boards have created, and how far merely regulated, a rising tide of wages. The effect of increases of wages upon employers, assets, and business. The relevancy of profits to wages, and the movement towards the adoption of higher standard for prescribing rates of wages rather than the mere prevention of sweating; prescribing the standard wage. Conjecture as to the future operation of the system in periods of falling as well as of rising markets.

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5. *The Artificial Regulation of Wages.* *By* G. S. Beeby.

The original conception of the Australasian experiments in industrial regulation was the prevention of sweating by the legal enactment of minimum wages.

To this has been added the statutory prohibition of strikes and lock-outs, and the consequent establishment of tribunals with power to substitute elaborate codes of working conditions, capable of legal enforcement, for voluntary contracts of employment. There is now sufficient data available to justify a critical analysis of this experiment.

Industrial arbitration has been successful in removing from Australia the reproach of sweated industries, and in raising the standard of unskilled workers.

It has proved that permanent conciliatory machinery is of value in bringing disputing parties together and effecting earlier settlement of serious strikes.

Constant open inquiry into the wages and working conditions of employees has been of great educational value and has led to more sympathetic consideration by the general public of the wage-earners' agitation for a higher standard of comfort, and to a wider public interest in economic problems.

It has failed to give the promised immunity from strikes and lock-outs, but has reduced the duration and intensity of serious industrial disturbances. By encouraging and facilitating the organisation of employees in many occupations which were not previously unionised it has increased the number of minor strikes.

It has contributed to a decline in the standard of efficiency in two ways: first, by largely increasing the wages payable to unapprenticed juniors, thereby reducing the incentive to follow fixed trades; secondly, by—in exercise of its arbitral functions in settlement or prevention of strikes—prescribing high minima, which become 'standards,' thereby removing the competitive incentive to inefficient workmen to improve their earning capacity. This decline in efficiency is accompanied by a reduction of output. In many occupations, notwithstanding the increase of wages, the average output per employee has substantially decreased. But this cannot be regarded as a result of artificial regulation of wages. It is clearly traceable to shortage of labour—the continued increase in demand for workmen, without a corresponding increase in supply.

Australia's greatest period of material development and progress has synchronised with its industrial experiments. Employers as a class have up to the present generally been able to adjust increased labour cost without reducing profits. But we are approaching the breaking-point. The elaborate codes which the Arbitration Courts substitute for ordinary contracts of employment, and the persistent increases in minimum wages, will shortly begin to encroach on profits. When this happens, and shrinkage of enterprise follows, a general reconsideration of the whole scheme of industrial regulation is inevitable.

Before long I believe we will sift the good results from the bad, and out of the whole system will retain the living wage, the maximum hours of employment, and a revised scheme of apprenticeship. We will draw a line below which there will be no competition for employment, but above which the ordinary economic forces will again come into play.

The elaborate machinery now existing will give way to a Board of Trade which will each two or three years prescribe a general living wage. The attempts to penalise strikes and lock-outs will give way to simple conciliation machinery, under which every threatened industrial upheaval will be openly inquired into and the parties encouraged and assisted to voluntarily settle their differences.

The worker will before long realise that we have reached the limit of artificial

regulation of wages, and that his energy in the future will be better directed to increasing the purchasing power of his sovereign, rather than to adding another sovereign to his weekly wage.

6. *The Development of Organisation in relation to Progress.* *By* W. R. Scott, *M.A., D.Phil., Litt.D.*

Though the name 'organisation' is comparatively new, the idea is old. In Mercantilism there was involved the conception of the organisation of States on a national basis instead of the mediæval one of a manor or city, and a somewhat similar tendency may be seen at the present time in the development of the policy of new countries. The view that the Physiocrats represent a revolt against Mercantilism is erroneous. There was really continuity of thought. While the Physiocrats aimed at an ideal of cosmopolitanism, organisation came to be considered as something emanating from the initiative of individuals, not from the State, as with the Mercantilists. Under the influence of Adam Smith this idea continued till biological studies gave as a by-product the conception of 'social organisms,' whence organisation acquired a new meaning in relation to the creating of such organisms or adding new functions to them. The implied reference to a social organism causes organisation to be used in an analogical sense, and there is a tendency to abstract the mode of organising from that which is organised, and to hypostatise the abstraction—as when organisation is termed an agent of production.

The modern conception of organisation, when duly limited and defined, is valuable in suggesting an organic reference; and as indicating that an organised body is something different from the parts which go to the making of it. But the term 'organisation' is generally applied to small groups of persons, which may behave antagonistically to each other. Hence, in this use of the word, modern organisation is narrower than that which the Mercantilists aimed at. Socialism, on the other hand, presents a more comprehensive idea of organisation, but one which most of its advocates now believe is unlikely to be brought into existence as a completed whole, and which can only be approximated gradually by successive stages.

In addition to what is now usually called organisation, there is also social organisation, which is often described as social betterment, social service, or social reform. This movement involves united action by the whole community for improving the condition of some section of its members, in the belief that such action is for the ultimate, if remote, benefit of the State. Instances are to be found in State-education, State-controlled immigration, labour exchanges, sickness insurance, invalidity insurance, conciliation or arbitration in labour disputes.

Social organisation differs from the primary form of State-activity (*e.g.*, the defence of the country or the administration of justice) in that, while both are administered by the State, the latter concerns all citizens, while the former relates much more nearly to certain groups only. Modern social organisation differs from that of the Mercantilists in being concerned in the first instance with the creation of immaterial wealth, though in the end it is likely to yield a vast return on the labour and outlay in material wealth also. But that return cannot be predicted as absolutely certain. In most cases the result of social reforms only appears after a long lapse of time, and therefore there is the danger that, in the interval before actual experience yields a verification or refutation of the special form of organisation, social welfare may be *pro tanto* diminished instead of being increased. Therefore the conditions under which social organisation must be carried on render it imperatively necessary that the widest and most accurate knowledge of economic and social conditions should be available, aided and supplemented by the tact and judgment of the man of affairs.

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7. *The Economic Ideal. By* Professor S. J. Chapman.

This paper was an attempt to define the main economic characteristics of the ultimate end that should be aimed at by social reform. On the productive side

the need of efficiency is obvious, but in addition production should be directly yielding in satisfaction and be responsive to demand. From these *desiderata* important practical corollaries can be deduced. Two maxims of distribution can be laid down—the one leading to distribution according to needs, and the other to distribution according to productive value. They appear to conflict, but analysis of fundamental ideas seems to show that their harmony is not inherently impossible. In consumption or demand the ideal is easily stated, but the reform of demand has hitherto proved itself a remarkably intractable problem. 'Individualising' betterment is of great value, but massive results can only be attained when it is aided by a suitable environment and measures calculated to mould class ideas. Socialism and Individualism, as commonly understood to-day, relate mainly to means. Advocates of both may agree as to ends; and to attain this agreement would save endless futilities in discussion and action.

SECTION G.—ENGINEERING.

PRESIDENT OF THE SECTION.—Professor E. G. COKER, M.A., D.Sc., M.Inst.C.E.

The President delivered the following Address at Sydney on Friday, August 21 :—

THE subject of stress distribution in materials, which I have chosen for this address, is not one which an engineer can claim as his peculiar province, for it has been and still is a fruitful field of investigation for the mathematician, the physicist and the geologist, and has always been so since the commencement of scientific inquiry; indeed, it must have been the source of speculation and controversy ever since mankind emerged from a primitive state, and began to fashion dwellings, weapons, and tools from the materials at command.

The development of architecture from the earliest dwellings of savage races to the great temples of Egypt and Greece, the bridges and aqueducts of the Romans, and the mediæval buildings of Europe, all bear witness to the accumulation of practical knowledge of the properties of materials and of the stress distribution in structures, which we cannot fail to admire, although we know far too little of the way in which these ancient structures were planned and constructed. The magnificent arched and domed buildings of the Roman period, and the stately cathedrals of later times with their wealth of architectural form—tower and spire, flying buttress and vaulting—all show how considerable was the practical knowledge of stress distribution possessed by the master builders who planned and carried out these great structures. We, who inherit these buildings as a precious legacy of bygone ages, have at our command far greater resources in the accumulated knowledge of centuries of scientific discovery and invention, and can build more complex structures—great bridges of steel, towering frameworks covered by a thin veneer of masonry, and floating arsenals of the most bewildering intricacy. All these we can show to our credit as the result of the steady increase of scientific knowledge applied to practical ends, but, even now, knowledge of the stresses which come upon these complex structures and machines is relatively small. Scientific investigations of engineering problems of stress still lag behind constructive ability, and defective knowledge is obscured more or less by approximate theories and buttressed by factors of safety, which serve in one instance perhaps, but show in others that they have merely given a sense of fancied security with no real basis, and are more properly factors of ignorance, to be discarded at the earliest moment. Who, for example, can say with certainty what is the stress distribution throughout the compression members of a great bridge, built up of complicated steel shapes and plates, united by stiffening angles, gusset plates, and innumerable rivets? There is probably good reason for the belief that a great strut is relatively weaker than a small one, when both are designed according to the same approximate formulæ now used in current practice, and engineers are unwilling to take the responsibility for such members in a great structure, without providing a very ample margin of safety to cover the contingencies arising from lack of precise knowledge of the strength of these members. So numerous are the problems which arise in the design and construction of machines and structures, that it is perhaps not unprofitable to

devote a short hour to the consideration of some of the available means which an engineer can use as a guide for his applications of science to construction, since of whatever kind are the professional activities he pursues, his place in the scheme of affairs mainly depends on his ability to make machines and structures for directing and modifying natural sources of power in known ways, or applying them to new purposes as scientific discoveries advance the boundaries of knowledge.

The power to do this depends, to no small extent, upon the ability to determine the distribution of stress in a structure, and the skilful manner in which material can be disposed for the required purpose.

It is of some help to our appreciation of the achievements of the great constructors of past ages, if we remember that they probably all held the erroneous view that materials of construction are perfectly rigid bodies, and, indeed, we know that as late as 1638 Galileo Galilei was of that opinion, and that he came to an entirely wrong conclusion as regards the stress distribution in a loaded cantilever.

It required the genius and insight of Robert Hooke to make a really great step, with his celebrated theory of the linear relation of stress to strain, and we can appreciate the glow of pride and satisfaction which he must have felt at his great discovery, when he records in 1675 that 'his Majesty was pleased to see the experiment that made out this theory tried at Whitehall, as also my spring watch.'

Hooke had, in fact, discovered the fundamental principle upon which a theory of the elasticity and strength of materials could be based, and it would be interesting to trace the great advances which were rapidly made from this new vantage-ground, whereby the main facts of the distribution of stress in simple members of structures became known, and a foundation was laid for the great advances of the mathematical theory. If I am silent upon the enormous developments of the modern theory of the strength of materials it is not from lack of appreciation, but because I do not deem myself adequately fitted to discuss the great work of the elasticians, which all engineers admire, and so few are equipped to follow with the full battery of mathematical tools which have been pressed into service in the pursuit of this great science.

Among the greatest of the services rendered by early pioneers was that of Young, who was the first to notice that the elastic resistance of a body to shear was different from its resistance to extension or contraction, and this led him to define a modulus of elasticity for materials in compression. As Professor Love remarks, 'This introduction of a definite physical concept, which descends, as it were, from a clear sky on the readers of mathematical memoirs, marks an epoch in the history of the science.'

From the standpoint of the engineer, nothing is of more practical importance than the great discoveries of Hooke and Young, that bodies like metal, wood, and stone are 'springy' and have a simple linear relation between stress and strain. It is probably within the mark to say that nine-tenths of all the experimental investigations on stress distributions in structures have been entirely based on the fundamental principles which they enunciated, and new uses are continually arising. The recent application of the steam turbine to the propulsion of ships produced a profound change in marine-engine practice, and incidentally involved an entire reconstruction of methods for obtaining the horse-power developed, which had been gradually perfected from the time of Watt, but were absolutely useless for the new system of propulsion. Hooke's discovery of the essential springiness of metals enabled engineers quickly to devise new instruments capable of accurately measuring the infinitesimal angular distortions of propeller shafts, and from these to determine the horse-power transmitted by the aid of an appropriate modulus.

The construction of tall buildings affords another example where advantage has been taken to determine the loads upon columns by measuring the minute diminutions of length as the structure proceeds, thereby affording a valuable check upon the calculations for these members, and a reliable indication of the pressures supported by the foundations.

The distribution of stress in buildings constructed of composite materials like concrete reinforced with steel has also been examined by similar methods, and

much data for guidance in future constructional work has been obtained, especially in the United States of America.

The still more difficult problems involved in the determination of the stresses in joints and fastenings of complicated structures have often been investigated by purely mechanical measurements of strain, and the experimental investigations of Professors Barraclough and Gibson and their pupils upon the distribution of stress due to riveted joints and curved plates of boiler shells afford a notable example of the successful application of the measurement of small strains to a stress problem of great complexity.

That 'science is measurement' is here sufficiently obvious, and it seems only due to the memory of that great engineer, Sir Joseph Whitworth, to refer to his great mechanical achievements of a true plane and well-nigh perfect screw, which enabled him to measure changes of one-millionth of an inch, and thereby gave experimental investigations of strains a new impetus, which is reflected in subsequent work on the subject. Nor must we forget the no less important exposition, by Kelvin and Tait, of the scientific principles of instrument construction which have done so much for the design of instruments for the precise measurement of strains.

Mechanical measurements cannot, however, completely satisfy all our modern requirements, since they are essentially average values, and fail to accommodate themselves to many of the problems which press for solution.

In the quest for exact experimental knowledge, the measurement of stress at a point becomes of paramount importance, and we may, therefore, inquire what further means the researches of pure science have placed at our disposal for the determination of stress distribution in materials.

It is well known that many materials when tested to destruction show a considerable rise of temperature at the place of fracture, especially in very ductile materials; but Weber was the first to discover that a metal wire when stretched within the elastic limit is cooled by the action of the load, and this result was deducted later from the laws of thermo-elastic behaviour of materials by Lord Kelvin, who showed that tension and compression loads produce opposite effects, and that materials which have the property of contracting with rise of temperature show thermal effects of the reverse kind. Although the changes of temperature produced by stress are small within the elastic range—less than 1° C. for most materials—yet their effect upon a thermo-couple is readily measurable if the equilibrating effects of surrounding bodies are neutralised or allowed for, so that stress distribution can be determined by thermal measurements at a point. The correction for such disturbing causes is usually an important factor, and is generally so large that experimental work is more suitable for the laboratory than the workshop; but if all necessary precautions are taken a linear relation of stress to strain can be shown to hold up to the elastic limit of the material, while above this point the break-down of the structure causes a rise of temperature of so marked a character that it has been utilised by several investigators as an indication of the yield point.

Experiments, upon members subjected to tension, compression, and bending, show that thermal phenomena afford trustworthy indications of the stress in materials so diverse as a rolled-steel section, a block of cement, and beams of stone and slate. Although no attempt appears to have been made to investigate stress distributions of any great complexity, it seems not unlikely that thermal methods of investigation will ultimately prove of considerable value.

The transparency of metals to Röntgen rays is another phenomenon which has often been suggested as likely to be of service for work on stress distribution in materials, and Mr. Howgrave Graham and I have examined a number of rolled metals under stress up to the breaking point, without, however, discovering any change in the appearance of the material as seen on a fluorescent screen. Although our experiments showed no perceptible change, it is, of course, not impossible that an effect may have escaped our notice.

Another and still more fascinating field of research on stress distribution is afforded by the doubly refractive properties of transparent bodies under stress, a discovery made by Sir David Brewster almost exactly one hundred years ago, and but rarely made use of since by engineers, although Brewster himself immediately saw its value for experimental purposes, and suggested that models

of arches might be made of glass, and the effects of stresses due to loading rendered visible in polarised light.

Brewster carried his investigations further, by the invention of a 'chromatic teinometer' for investigating the nature of strains, and consisting of plates or bars of glass subjected to flexure in definite ways for comparison with the body under stress.

At a much later date (1841) Neumann developed an elaborate theory for the analysis of strain in transparent bodies due to load, unequal temperature, and set, while, still later, the youthful genius of Clerk-Maxwell supplied an algebraic solution for the stress distribution in any plate subjected to stresses in its own plane.

The early history of the development of this branch of science is, in fact, remarkable for notable contributions at long intervals of time, and the almost complete disregard by engineers of its practical importance.

The application of optical investigation to the determination of stress distribution in engineering structures and machines has, however, been hindered by causes which, although apparently insignificant, have been very real obstacles, and among these was the absence of a transparent material which could be fashioned into shapes suitable for investigating technical problems. It is not an easy matter, for example, to construct a glass model of a bridge free from internal stress, in the manner suggested by Brewster; and, moreover, glass is extremely fragile under load, especially in cases where the stress distribution in it varies very much, while the cost of construction is very great. Happily there is now no necessity to employ glass for experimental investigation on engineering problems, since modern chemistry has supplied artificial bodies, such as the nitro-cellulose compounds used for many trade purposes, which have optical properties very little inferior to glass, are able to bear great stresses without injury, and also are capable of being fashioned with the ease and certainty of a wooden model. Photographic processes are also able to reproduce the brilliant colour effects caused by stress in transparent materials, so that permanent records can now be made for future reference.

The construction of polariscopes for examining models on a large scale is very essential for technical research, and the great scarcity of Iceland spar of sufficient purity and size for use as Nicol's prisms has caused much attention to be paid to the construction of apparatus for producing plane polarised light by the aid of sheets of glass. Fortunately this presents little difficulty, and although the light is not nearly so well polarised as that obtained from a Nicol's prism it is sufficiently so for the purpose. Large quarter-wave plates of mica have also been constructed by my colleague, Professor Silvanus Thompson, F.R.S., for obtaining circularly polarised light, and these have proved sufficiently exact and exceedingly useful for large models.

It is of importance to show that the stress distribution revealed by a polarised beam of light passing through an elastic transparent material in no way differs from that obtained by other means, and evidence is available in modern researches, especially by Filon, that the experimental results obtained with glass agree with those of the theory of elasticity, while a satisfactory agreement of a similar kind has also been obtained with nitro-cellulose compounds, although not in so complete and direct a manner. Such an agreement may be expected on theoretical grounds, since the values of the elastic constants do not affect the fundamental equations for stresses in a plane, and although for three-dimensional stress the effect of the stretch-squeeze ratio causes some difference, yet this is usually negligible.

Most of the physical constants of glass have been determined with very considerable accuracy, but other transparent substances have so far received little attention, and their optical constants are not well known. The stress-strain relations of glass and nitro-cellulose have been determined with considerable accuracy, and a useful idea of their relation to metals may be gained from the values of the stretch-modulus, E, and the stretch-squeeze ratio, σ.

The accompanying table shows some average values for a few important materials, and it is of interest to note that the stretch-squeeze ratios of cast iron and plate-glass are very similar, while the values of the stretch modulus are nearly as three to two. These two materials also possess other like charac-

teristics: they are both very brittle, and possess well-developed crystalline structure, so that we may expect the properties of cast iron under stress to be very faithfully followed by plate-glass.

Material	E	σ
Steel	30,000,000	0·25
Wrought iron	28,000,000	0·28
Cast iron	15,000,000	0·25
Plate-glass	10,500,000	0·23
Nitro-cellulose	250,000 to 300,000	0·40

The high values of the stretch modulus for steel and wrought iron are not, apparently, approached by any transparent material having similar ductile properties, but although nitro-cellulose has a stretch modulus of rather less than one-hundredth that of steel, its stress-strain properties are not unlike. In some recent experiments with a miniature testing machine fitted with an arrangement for recording the stress-strain relations of xylonite throughout the whole range of stress up to fracture, the main characteristics of steel appear on a very much reduced scale, and give additional confidence that the results of optical experiments on this material are applicable to metal structures.

The complete analysis of stress distribution in a plate is not, however, a simple matter, and the analysis of Clerk-Maxwell was intended to provide a solution based on the properties of the isochromatic and isoclinic lines, coupled with the law that the optical effect is proportional to the difference of the principal stresses at a point, and to the thickness of the plate.

A principal stress perpendicular to the bounding planes is assumed to have no optical effect; but since many cases have arisen where there are three principal stress components, it seemed desirable to examine such a case experimentally.

It is a matter of some difficulty to arrange apparatus to stress a specimen in the direction of the incident beam, and at the same time observe the optical effect free from disturbing causes, since a transparent medium must be interposed for applying the required load, and this will be subject to stresses which may interfere with the optical effect on the specimen.

Some observations on circular plates clamped at the edges and uniformly loaded over one face, showed that the bending stresses produced in the plate caused very little optical effect, since the tension and compression stresses neutralised one another, while the shear effects also appeared to be practically negligible. The only remaining stresses of importance were those caused by the clamping plates at the boundary, which produced radial and circumferential stresses having circular symmetry, and as the optical effects of these latter disappeared at a small distance from the edge, a field of view was obtained in which the optical effects of load applied perpendicularly to the plate were quite small, even when the internal stresses were very great.

Two circular plates clamped together to enclose a space between them may therefore be used as windows for observing the effect of a uniform pressure upon a transparent specimen, which latter may be a plate with its faces parallel to the end plates closing the chamber. If cubical compression is applied by a fluid, the principal stresses in the plane of the plate produce opposing optical effects, and any remaining effect is due to perpendicular pressures on the faces. The arrangement of experimental apparatus, therefore, took the form of a pair of transparent windows separated by an annular disc, and firmly clamped together by collars. The central chamber so formed was subjected to pressure of air, or other fluid, up to about one thousand pounds per square inch, and afterwards the specimen was introduced and the same pressure applied; but no visible change of effect could be observed. Finally, the specimen was set in the field of view outside the chamber, and pressure again applied by the fluid, but still no change was apparent. In all three cases the optical effects produced were small, and practically alike, so that the experimental evidence appears to warrant the conclusion that a principal stress in the direction of an incident beam of

polarised light has no optical effect in a thin plate, or at any rate is so small that it may be neglected.

That the retardation between the ordinary and extraordinary rays is proportional to the stress difference perpendicular to the incident beam within the elastic limit of the material may, therefore, be taken as reasonably accurate, although future research may show that it is only an approximation, or even that it is more accurate to commence from a fundamental strain equation; but according to present knowledge there appears to be no warrant for such a procedure.

A more pressing difficulty arises with regard to the optical constant connecting the wave-length retardation with the stress difference. The recent researches of Filon on glass show that the value of this constant is curiously dependent on the previous history of the material, especially as regards its heat treatment. Until further knowledge is gained on this matter it appears to be necessary to guard against errors in stress measurement from this cause by a careful selection and treatment of the material used, since for other artificial bodies we may find that the variation in the constant is not less in magnitude, and is at least as complex as in glass. In some instances the stress optical coefficient may be dispensed with, and Filon has shown, in cases where a theory of stress distribution has been worked out and it is desired to compare it with the results of optical measurements, that the isoclinic lines offer many advantages, since they are independent of photo-elastic constants, and the material need only be subjected to small stresses.

The experimental analysis of stress distribution in a body depends on the possibility of finding the magnitudes and directions of the principal stresses at every point, and in practice it is found the simplest plan to determine the directions of stress from the lines of equal inclination obtained in plane polarised light, and to measure the stress difference by comparison with a wave-length standard, such as a Babinet compensator, or by comparison with a simple tension member set along one of the lines of principal stress, and loaded until the total effect produced is a dark field denoting a zero value. The difference of the principal stresses is then measured in terms of a simple tension. This alone is insufficient to determine the distribution, unless one of the principal stresses is zero, and, in general, another independent measure must be obtained. This is very conveniently supplied, as Mesnager suggested, by the change in the lateral dimensions of the plate under stress, since this change may be taken, in the absence of a third principal stress, as proportional to the generalised sum of the principal stresses throughout the thickness.

The determination of the lateral strains in a comparatively thin plate, forming part of a model of a machine or structure, necessitates measurements of extremely minute linear quantities. If, for example, a plate of xylonite is taken, of the maximum thickness obtainable for optical work, a simple calculation shows that these strains must be measured to an accuracy of one or two millionths of an inch. Several instruments have been designed and constructed for this purpose, to fulfil conditions which appear to be essential for successful use. It is necessary to avoid all chance of injury to the surface of a transparent material, so that the measuring points of an instrument can only be pressed lightly against the surfaces, and the weight must, therefore, be supported independently of the model. In instruments so far constructed, the measuring mechanism is carried on a U-shaped frame, for convenience of movement from point to point of the specimen. One measuring needle is secured and operated by a calibrating screw, and the other is free to move a multiplying lever system, and thereby tilt a mirror to give an angular deflection, which latter is calibrated by reference to the standard screw when the instrument has been finally secured in place. In recent work the labour of accurately setting the instrument in a number of different positions has proved so great, that my assistant, Mr. F. H. Withycombe, has designed a useful adjunct in the form of a mechanical slide-rest, to effect the required changes easily and expeditiously. In one arrangement, a bracket carries the measuring instrument on a three-point support, and movement is effected by slides arranged to give displacements along three axes at right angles, and their amounts are measured by micrometer screws to an accuracy of rather less than one-thousandth of an inch.

These methods of stress determination avoid the difficulties of the Clerk-Maxwell analysis, which necessitates the determination of the equations to both families of isochromatic and isoclinic bands, usually a mathematical problem of considerable complexity. In some simple cases Mr. Scoble and I have verified the accuracy of the method of lateral measurements for determining the sum of the principal stresses, by comparing the calculated stresses with the experimental values obtained in a plate of transparent material. We have lately carried these experiments a stage further, and have shown that the measured sums of the principal stresses in steel agree with the calculated values. This experimental solution, in fact, gives the stress at a point in a plate, if the conditions are those assumed by the mathematical case of a plate where generalised equations of stress apply.

It is at once obvious, if the utility of experiments on models of this kind is admitted, that experimental evidence is available on a variety of practical engineering problems covering a very wide field of practice, not merely qualitative, but quantitative, and approximating to the needs of the physicist and mathematician, and well within the known variations of the materials with which the engineer has to deal in his daily practice.

During the last few years much attention has been paid to the determination of the stresses in structural elements of primary importance, but only a small number of cases have been examined, since even the simplest problems have proved somewhat difficult, and much time and labour have been spent in perfecting optical and mechanical appliances to suit the special conditions required for investigations on transparent models. A simple example of a case easily examined and of practical importance is that of a tension member subjected to an eccentric load. The optical effects here show a linear distribution of stress due to the combination of direct pull and bending, while the neutral axis moves towards the tension side as the stress increases. Not only can these effects be measured, but if the specimen begins to fail some indication is obtained of the way in which the stress distribution is changed to meet the new conditions, and there is found a tendency to an equalisation of the maximum stress at the boundary, although at present the form of the curve of distribution beyond the elastic limit is largely conjectural.

A case like that of a very short member subjected to direct compression is also not without interest, partly because it reveals unexpected difficulties. In the first place it is not easy to apply a pure compression stress, and if the surfaces in contact are not of the same materials it appears to be practically impossible, since the lateral changes are unlike, and shear stress is therefore produced at the plane of the surfaces in contact. In a short member this shear has a very important influence, and by interposing a thin layer of a material, such as india-rubber, between the pressure plates and the short transparent block, the artificial shear effect produced by the india-rubber is easily shown to influence the distribution throughout, and to increase the stress in a very marked way. Experiments on transparent materials show that the increase of stress may be twenty per cent. or even more. Such an effect is known to take place when cubes of stone are crushed between lead plates, and optical investigations on models have enabled a quantitative measure of the effect to be ascertained in this and other cases, thereby confirming the theoretical investigations of Filon on the distribution of stress in such members under various practical systems of loading.

The local effects produced near the points of application of a load are usually of considerable importance, and their influence on the stress distribution in beams has been examined by Carus-Wilson.

The stress effects produced by discontinuities in materials is also of considerable interest, and the cases arising from the necessities of construction are infinite in their variety.

The practical importance of an accurate knowledge of the change in stress distribution produced by changes of section in a member is so thoroughly appreciated that it needs no insistence, and it has received much attention from a mathematical point of view. Thus the local effect of a spherical cavity in a member subjected to uniform tension or compression load has been shown by Love to double the intensity very nearly, while Kirsch has shown that a small

cylindrical hole in a tension member trebles the stress intensity. If the hole is elliptical the increase of stress may be still greater, and Inglis has shown, among other interesting cases, that if the minor axis of the ellipse is parallel to the direction of the applied load in a tension member, the stress intensity is increased by an amount measured by twice the ratio of the axis of the ellipse.

A crack, considered as the limiting case of an elliptical hole, is thus seen to give extremely great stresses at the ends, tending towards infinite values for an extremely fine crack.

Optical experiments afford an independent means of examining the alterations of stress intensity produced by discontinuities, and the results are found to agree remarkably well with those obtained from the theory of elasticity. The stress at the boundary of a small cylindrical hole in a plate has been found to be almost exactly three times the stress in the full plate, and the effects of holes comparable with the width of the tension member have also been examined in some detail.

In the case of a rivet just filling the hole and exerting no tangential effect at the boundary, there is a lessened tension stress across the minimum section at the boundary hole, accompanied by a marked radial tension. These effects have been recently confirmed in a mathematical discussion by Suyehiro. Other cases give satisfactory agreement with calculation, and we may therefore feel some confidence that experimental investigation will prove useful in some of the very complicated cases arising out of engineering practice where analysis is difficult, if not impossible.

The effects of overstress in materials may also be examined by optical means, and although the laws relating to stress distribution in overstressed transparent material are not known, the general effects observed in simple cases are fairly evident. If, for example, a tension member of glass is stressed, there is no ductile yielding of the material, and the stress will therefore rise very rapidly at the boundary of a small hole, and fracture will therefore occur with a moderate load. If, however, a ductile transparent material is employed, and the material shows signs of failure at the hole, the break-down of the structure spreads outwards as the load is increased, until we may have a condition in which within the elastic limit the curve of stress intensity at the minimum section accords with calculation, but at the overstressed part the stress tends to equalise, and the curve of intensity tends to become horizontal near the hole. The mean value of this part of the stress distribution may be inferred from the difference between the total load and the measured values below the region of failure; but the true distribution of the overstress has not been accurately determined, so that the shape of this peak is largely conjectural.

The effects of groups of rivets such as occur in bridges, boilers, and structural members of all kinds, afford ample scope for further inquiry; but before more exact knowledge can be gained of the condition of stress in a complicated riveted joint it appears necessary to examine thoroughly the very simple cases.

Mr. Scoble and I have examined the case of the load applied by one rivet to a plate with various amounts of overlap, and the stresses around the rivet holes have been measured with fair accuracy.

Other interesting cases of discontinuity in structure are afforded by the engine hatchways, gun-turrets, funnel openings, and the like, in ships' decks, and some progress in this direction has been made by experiments on model decks, subjected to loads like those produced when a vessel meets the waves due to a head sea.

Even if the utility of transparent models is left out of account, it is generally acknowledged that many engineering problems are often simplified by the use of models of machines and structures on a small scale, where circumstances forbid experimental examination of the actual work. No defence of their use is, I think, necessary, since the employment of models is a characteristic feature of British methods, not limited to engineers. Kelvin did not disdain their use, and his successors, who have done so much to advance knowledge of the ether and the atomic dust, have freely employed their great ingenuity in the construction of mechanical models and diagrams to explain their views, as in the Lodge cog-wheel diagrams of the ether, the planetary systems of atoms of J. J. Thomson and Rutherford, and the grouping of elements by Soddy.

Engineers have not the same great difficulties which confront those who are advancing the boundaries of pure science; their models are very much what they please to make them; but, even then, problems arise which are sufficiently difficult to tax all the resources of applied science. The behaviour of models considered as similar structures is, therefore, a subject which engineers are bound to investigate in order to determine the effects of fixed and moving loads, the action of wind, the pressure and frictional effects of steam and other fluids, and many other problems.

In the majority of cases the simplest and the most direct method is the experimental study of a model, from which to obtain the data required for calculating effects on a full-sized structure, and hence the laws of similarity have received a very close scrutiny.

Although most valuable information can be obtained from models, their usefulness is clearly limited. The effects of the dead weight of a structure are proportional to the cube of the linear dimensions, and are, therefore, not usually measurable on a model except in exceptional circumstances, as, for instance, where elastic jellies are employed, as in the well-known investigations of Pearson on the stress distribution in reservoir dams. Nor are questions of stability easy to solve, since the forces producing instability are proportional to the size of the model. On the other hand, stress effects due to applications of load may be measured by the strains produced in a model of the same material, if the loads are proportional to the squares of the linear dimensions. The effects of applied load are studied even better in a model constructed of transparent material, since the variation of stress from point to point can be studied with much greater ease and certainty.

As detailed models of this latter kind present some variations from the usual laws of similarity, it may be of interest to indicate their nature. Questions of deformation clearly involve the elastic constants of the transparent material and their relation to those of the proposed structure, while stress distribution in the solid is influenced by the value of Poisson's ratio. This latter effect is quite small for glass, but may become appreciable with other substance. It is negligible in a model of any material which approximates to a thin plate stressed by forces in its own plane.

The optical effects for any given load are, moreover, independent of the thickness of the material, and depend upon the stress difference, so that colour effects are obtained which may be regarded as pictures of shear stress throughout the model. Modern researches on ductile materials like structural steel indicate that such materials fail at some limiting value of shearing stress, and since the places where these limiting values are reached in the model are visible to the eye, the weak places in the design of a structure can be ascertained and a faulty design corrected by purely experimental means.

In this connection it is of interest to mention that M. Mesnager, the chief engineer of bridges and roads to the French Government, has recently constructed an elaborate model in glass of a design for an arched bridge of about 310 feet span. This investigation was considered advisable for a work of this magnitude constructed of reinforced concrete, in order to check the calculations, especially of maximum stresses in the arched ribs, which latter were assumed to be fixed at the ends.

The effects of reinforcements were allowed for by determining equivalent sections of glass for the members of the model. Many difficulties had to be overcome in the production of a model free from optical defects, but these were all successfully surmounted. The stresses in the model were determined by aid of a Babinet compensator, and formed a valuable check upon the calculations for a structure of this great magnitude and somewhat unusual design.

In this brief and incomplete account of a small branch of applied science relating to engineering the fundamental importance of discoveries in pure science is manifest.

The discoveries in pure science and their innumerable applications to practical ends are ever a potent factor working for the common good, and the value which the British Association places upon applied science was most cordially voiced by Professor Bateson in his Portsmouth Address when he said : 'To the creation of applicable science the very highest gifts and training are well devoted,' and,

'The man who devotes his life to applied science should be made to feel that he is in the main stream of scientific progress. If he is not, both his work and science at large will suffer. The opportunities of discovery are so few that we cannot afford to miss any, and it is to the man of trained mind, who is in contact with the phenomenon of a great applied science, that such opportunities are most often given'; and, again, 'If we are to progress fast there must be no separation between pure and applied science. The practical man with his wide knowledge of specific natural facts, and the scientific student ever seeking to find the hard general truths which the diversity of Nature hides—truths out of which any lasting structure of progress must be built—have everything to gain from free interchange of experience and ideas.'

Engineers who are more immediately concerned with the problems of directing the great sources of power in Nature for the use and convenience of man are indeed grateful to our President for these inspiring words, and trust that the ties which unite investigators in pure and applied science will never slacken, but will knit together more closely for a joint advance to a more perfect understanding and utilisation of the laws of Nature.

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *Aviation Research. By* Professor J. E. PETAVEL, *F.R.S.*

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2. *Railways and Motive-Power.*
By Professor W. E. DALBY, *F.R.S., M.Inst.C.E.*

The object of the paper was to initiate a general discussion on the question of railway development in Australia. Various curves relating to the development and cost of working of English railways were shown on the screen. The question of motive-power was then considered and the advantages of the locomotive and the electric motor compared. Curves were also shown illustrating the proportion of fuel actually used to draw a train as compared with the quantity fired in the furnace of a steam locomotive and in the furnace of a central station in the case of electric traction. Other curves illustrated the limits of economy and speed of a steam locomotive and the electric motor compared together in relation to special problems in connexion with suburban traffic.

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3. *A Transmission System suitable for Heavy Internal-Combustion Locomotives.*[1] *By* HEDLEY J. THOMSON, *Assoc.M.Inst.C.E., M.I.E.E.*

The author pointed out that the slow progress made in the use of internal-combustion engines for heavy traction has been due to the want of suitable variable-speed control mechanism. He enumerated four types of variable-speed gear, and gave in detail, with diagrams, a technical description of the Thomas electro-mechanical transmission, which is put forward as the most suitable for the class of work referred to. With this system, so long as the prime mover, when in direct drive, can overcome the resistance encountered, the transmission is direct and altogether mechanical. At all other times the power of the prime mover is divided by means of planetary gearing into two parts, one portion being applied to the load by electrical means and the other mechanically. The electric transmission ensures that ease of control characteristic of all electrical drives, and yet, owing to the large proportion of the total power transmitted mechanically, the system is not subject to the heavy losses unavoidable with a system wholly

[1] Published in the *Electrician*, vol. lxxiii., p. 826.

electrical. It was stated that for general locomotive work on a route with give-and-take grades, only 1 per cent. of the total energy of the prime mover would be lost in the electrical apparatus used.

Particulars were given of results calculated as obtainable with the system as applied to 1,000 h.p. express locomotive, and in conclusion it was suggested that the system should be of special interest to railway engineers, particularly in countries where difficulties are encountered in providing satisfactory supplies of water and fuel for steam locomotion.

4. *The Canberra Plan.* *By* WALTER BURLEY GRIFFIN.

Canberra is the name of the future Federal Capital of the Commonwealth of Australia. The author discussed the principles underlying modern town planning with special reference to the lay-out of an administrative capital. It was shown how these principles have been applied in the scheme adopted at Canberra and how the natural features of the landscape have been utilised.

5. *Development of the Port of London.* *By* C. R. S. KIRKPATRICK.

TUESDAY, AUGUST 18.

The following Papers and Report were read :—

1. *The Behaviour of Metals under Strain.* *By* WALTER ROSENHAIN, *B.A., D.Sc., F.R.S.*

For a rational understanding of the behaviour of metals under strain the truly crystalline character of all metals and alloys in their normal (cast or annealed) state is of fundamental importance. Evidence for this fundamental proposition is readily obtained by the microscope in a variety of ways, including the development of 'etch figures,' 'negative crystals,' and the 'oriented lustre' of crystalline aggregates. The manner in which a crystalline aggregate is formed when a material undergoes solidification by a process of dendritic crystallisation such as is typical in metals is illustrated by the building up of aggregates of cubical blocks, a process which is shown by the aid of the cinematograph. By the same means the behaviour of etched metal surfaces under oblique light is demonstrated. The behaviour of crystals and of a crystalline aggregate under plastic deformation is next considered, and the manner in which a crystal can undergo deformation by a process of slip on its cleavage or gliding planes is explained and illustrated by the cinematograph, a summary of the evidence upon which our present knowledge of the true nature of plastic deformation is based being given and illustrated.

The more detailed and difficult questions connected with the deformation and fracture of metals which have received increasing attention recently are next considered, including such phenomena as 'fatigue,' testing by, and failure under, shock or repeated impact, and the phenomena of semi-plasticity and elastic recovery. The behaviour of metals at high temperatures is also discussed, and the explanation of these phenomena afforded by the modern development of the theory of an amorphous phase in metals, as originated by Beilby and extended by the author and his collaborators, is summarised.

2. *The Testing of Materials.*[1] *By* Professor W. E. DALBY, *F.R.S., M.Inst.C.E.*

In this paper a short account of some modern photographic methods of testing materials was given. The practice of showing the structure of metals by

[1] Published in *Engineering*, September 4, 1914.

means of microphotography has steadily developed during the last few years. The author has recently applied a photographic method for obtaining a record of the relation between the load and extension of metals right up to the breaking point. The diagrams taken in this way show very clearly the peculiarities of the metals at their yield points, and also the load actually on the specimen at the moment of fracture. The combination of the two methods offers a promising field for research. Some photographic records and microphotographs were exhibited on the screen.

3. *The Humphrey Pump.* *By* H. A. Humphrey, *M.Inst.C.E.*, *M.I.E.E.*

The paper explained the principle, theory, and construction of these pumps, and concluded with a description of the two most important installations—the plant at the King George V. Reservoir at Chingford, Essex, where five pumps each lift 40 million gallons per day to a height of 30 feet; and the scheme for draining Lake Mareotis now being carried out for the Egyptian Government at Mex, near Alexandria, where eighteen pumps are ultimately to be installed, each capable of lifting 100 million gallons per day to a height of 20 feet.

4. *The Stress Distribution in Short Compression Members.* *By* Professors Coker *and* Filon.

Short compression members are occasionally used for constructive purposes but more especially for tests on materials like brick, stone, and concrete, which are almost invariably used in compression. In all such cases the mode of application of the load is an important factor, and its influence on the stress-distribution is known to be great.

This is recognised in the testing of engineering materials, and care is taken to ensure as uniform a distribution of load as possible over the end faces of the loaded member. Occasionally these faces are ground to approximately true planes by means of emery wheels or the like, in order to obtain a uniformly even bearing, and when the size or material of the specimen makes this impracticable the specimen is often faced with plaster of Paris for the same purpose.

A convenient method of investigating the stress at any point of a short compression member of rectangular section is afforded by the optical effects produced in a transparent model, combined with mechanical measurements of the lateral changes produced by the load.

In the experiments described in the paper a special form of compression-testing-machine was used, having one fixed pressure-plate, while the other has a slight frictionless movement in the direction of application of the load, and this latter is weighed by a system of levers. Experiment shows that a block of transparent material subjected to compression between steel or brass plates is never uniformly loaded owing to tangential stress at the planes of contact produced by the lateral changes of the two different materials. If a very extensible material is interposed between the specimen and the pressure-plates of the testing-machine, a very marked effect is produced of a similar nature to that obtained when a fine-grained homogeneous stone is stressed between lead plates.

Approximately pure compression-stress may be obtained when the compression-plates are of the same material as the specimen, and measurements of stress distribution in various cases were described and compared.

5. *The Artificial Electrification of the Atmosphere.* *By* Sir Oliver Lodge, *F.R.S.*

6. *Report on Stress Distributions in Engineering Materials.*

See Reports, p. 200.

7. *The Stresses in Built-up Columns.* *By* H. G. S. Delepine, *M.Sc.*

WEDNESDAY, AUGUST 19.

Joint Discussion with Section M (Agriculture) on Irrigation.
See p. 655.

The following Papers were then read :—

1. *The Dynamic Increment of a Single Rolling Load on a Supported Beam.*[1] *By* Professor H. CHATLEY, *B.Sc.*

The author suggested the use of the following formula for the dynamic increment of a single concentrated rolling load on a beam supported at both ends, the load being at the centre,

$$\delta F = W\left[\frac{1}{1-\frac{2c}{3}} - 1\right].$$

He showed that this is a close approximation to the solution of a complex differential equation which states the conditions of dynamic equilibrium in the given case.

The dynamic increment is due to the vertical accelerations experienced by the load as the result of the deflection of the beam, and is of course liable to a 'compound interest' effect. The latter will not ordinarily more than double the effect due to the static deflection alone.

δF = the dynamic increment of the load W.
V = the horizontal velocity of the load.
L = the span of the beam.
E = the modulus of elasticity of the material of the beam.
I = the moment of inertia of the beam section, assumed constant.
g = the gravitational acceleration.
$c = WV^2L/gEI$.

2. *The Change in the Modulus of Elasticity and of other Properties of Metals with Temperature.*[2] *By* Professor F. C. LEA, *D.Sc., and* O. H. CROWTHER, *M.Sc.*

The paper described experiments that had been carried out to determine the influence of temperature, varying from 15° C. to 650° C., on some of the properties of metals. The specimens were heated in an electrically heated furnace, the temperature of which could be maintained nearly constant for some hours, and were loaded by means of a horizontal hydraulic-lever testing machine. The form of the specimens and the arrangements used for connecting them to the shackles of the machine and also a special extensometer were described. Temperatures were determined by iron-constantin thermo-couples. The effect of temperature on the breaking stress, yield point, construction of area, elongation per cent., and the modulus of elasticity of mild steel and other metals was shown by curves plotted from the results of the experiments. The modulus of elasticity of mild steel was shown to vary from 13,000 tons to 6,000 tons per square inch as the temperature varied from 15° C. to 630° C. The breaking stress of mild steel as measured on the original area was shown to be a maximum at about 250° C., but the stress obtained by dividing the breaking load by the fractured area was a minimum at this temperature. The modulus of elasticity of micro copper was shown to change from 5,100 tons per square inch to 3,270 tons per square inch as the temperature varied from 15° C. to 650° C.

3. *A Theory of Work Speeds in Grinding.* *By* J. J. GUEST.

[1] Published in *Engineering*, September 11, 1914.
[2] Published in *Engineering*, October 16, 1914.

SYDNEY.

FRIDAY, AUGUST 21.

After the President had delivered his Address (see p. 490) the following Papers were read :—

1. *Irrigation in New South Wales. By* A. B. WADE.

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2. *Irrigation in Lybia.*
By Professor LUIGI LUIGGI, *D.Sc., M.Inst.C.E.*

The paper was prefaced by a general survey of the many works of general economic importance undertaken in Lybia—that is, the region round Tripoli and Bengasi—since its occupation less than three years ago by Italy. All these works are arranged according to a plan prepared by Professor Luiggi in view of the future development of agriculture in Tripolitania and Cyrenaica, not only as it must have been in Roman times, but as it can be further improved by modern implements and methods of cultivation, with the assistance of scientific irrigation.

Tripolitania, for the most part, is a flat country, slightly elevated above sea-level, with a hot and dry climate, and a scanty rainfall during the winter months and totally absent for two-thirds of the year, ranging from about 20 inches near the coast to 10 inches near the table-lands, and disappearing altogether further inland. The soil within the line of the 15 inches rainfall is sandy, but adapted to the culture of cereals of rapid growth, and for breeding sheep and especially goats. The rainy season is from November to February, and with proper cultivation—thanks to the abundance of sunshine even in winter —a good crop can be raised, ready to be harvested in March or April. Then begins the hot, dry season, and, where there is no irrigation, everything dries up.

Cyrenaica is rather a plateau-land, some 2,500 feet above sea-level, very undulating, with a milder climate and a rainfall of from 15 to 30 inches, so that ordinary crops, fruit trees, olives, vines, etc., can grow; besides date-palm trees, which form an important item in the agriculture of Lybia. But then the summer months are hot and dry, and unless some sort of watering is applied to certain classes of trees, many would die, especially in years of drought.

Thus practically the future development of Lybia depends more or less on irrigation. At present irrigation, as practised by the natives, is very rudimentary, but most ingenious. Owing to the great permeability of the soil there are no running streams in Lybia—or, at least, they may run occasionally, but only for a few hours after a cloud-burst. All the water passes rapidly into the subsoil and has to be raised from wells by means of buckets operated by camels; and thus only limited zones near the coast—where the surface is nearer to the water-plane—can be irrigated with profit. A very clever artifice is adopted to reduce evaporation. For this purpose on the same area to be irrigated are grown first palm trees, which form a sort of sunshade and a protection for the successive growth of orange or other fruit trees, which in turn shelter the plants to be grown on the surface, such as ordinary vegetables or lucerne, and to these the irrigation water is directly applied. In this way excess of sunshine and of ventilation are avoided and evaporation from the soil reduced to a minimum. At the same time three different crops are grown on the same plot of land, which is thus utilised to the fullest extent.

This method of irrigation, which is practised also in some parts of Sicily and must be of Roman origin, can be applied only to limited zones and where the water-plane is not more than 20 to 30 feet below the surface.

For irrigation on a larger scale, as there are no superficial streams, it is necessary to collect the rainfall from the mountain-sides and store it up in artificial lakes formed by dams. This was practised by the Romans, and we find in Lybia the ruins of many masonry dams and cisterns, some of which are being restored and will soon be again in working order. In the meantime some more important reservoirs are being considered and will soon be started. They

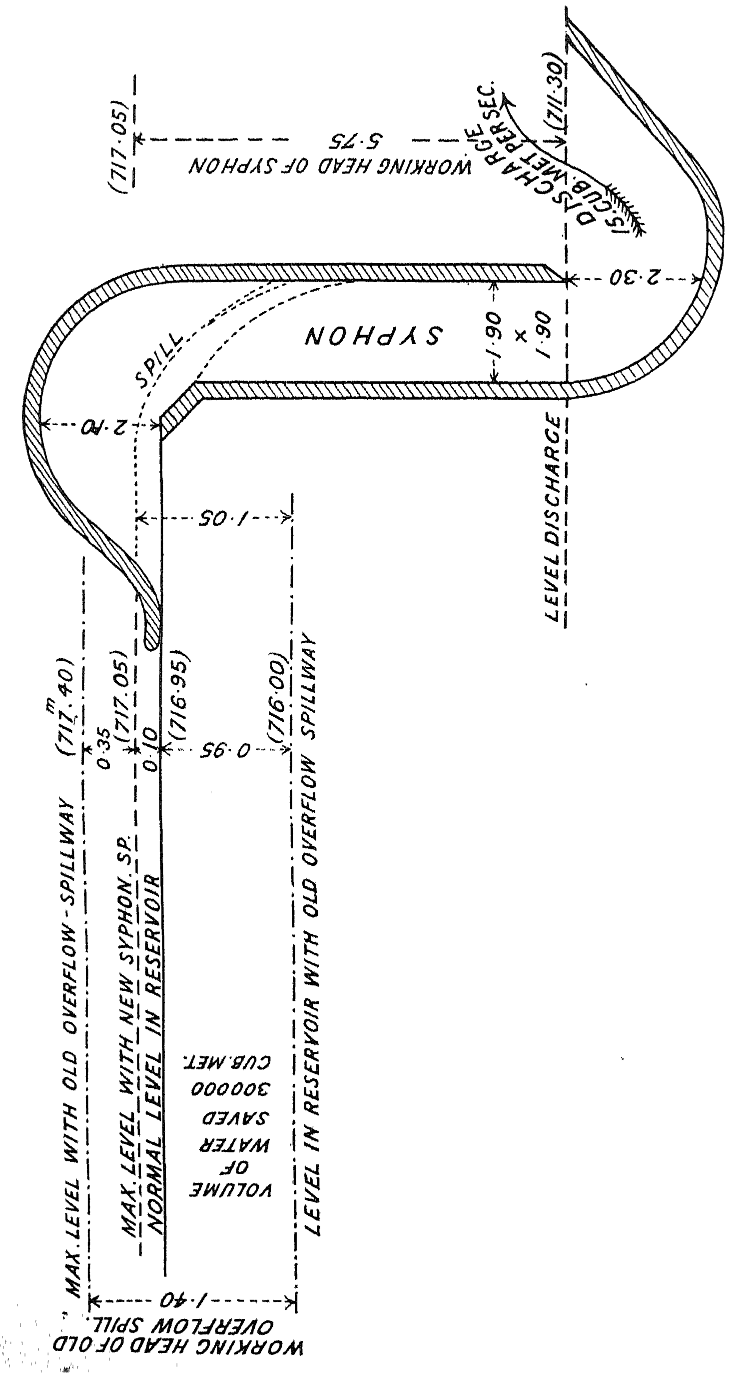

Diagram of Old Overflow-Spillway and of New Automatic Syphon-Spillway, as applied to the Lagolungo Dam.

For details see Professor L. Luiggi, *Dighe recentemente costruite in Italia.* '*Giornale Genio Civile*,' Roma, 1914.

will be formed by rock-fill dams, which are the best adapted for the natural conditions of the country, where labour is scarce and inefficient, good materials rare, and earth tremors rather frequent.

Rock-fill Dams.—The rock-fill dams can be built almost entirely by mechanical implements served by a few good workmen, and if the slopes do not exceed about 30 degrees the dam can resist any shock of earthquake without great damage, and in any case repairs are easy. This type of dam is very common in the Western States of America, and has been adopted with success also in Italy in the valleys of Cenischia, Biaschina, and Devero.

A special feature of the new reservoirs will be the 'automatic syphon-spillways' applied by Mr. Gregotti to many dams and canals both in Italy and elsewhere. It consists of a tube in the shape of a syphon, generally of square section, made of ferro-concrete, and capable of discharging from 1 to 15 cubic metres (525 cubic feet) per second, according to section and head, and if larger discharges are necessary then several syphons are distributed side by side up to ten. As soon as the water in the reservoir exceeds by 2 or 3 inches the normal level, the syphon is automatically primed, owing to the special conformation of its top-lip, and begins to act with full discharge till the level in the reservoir is lower than the lip of the syphon, when air gets in and the flow ceases.

The velocity of the water in the syphon is that due to the difference of level from the reservoir and the outlet of the syphon, and thus is greater, and the discharge is correspondingly greater, than in an ordinary overfall-spillway, where the velocity is due to the more limited head between the level in the reservoir and the sill of the spillway.

At equal discharge the syphon-spillway works better and costs much less than the usual overfall-spillway.

For example, in the Lagolungo reservoir near Genoa, the old overflow-spillway required a head of 1·40m. of water (4′ 8″) and a volume of 440,000 cubic metres of water (more than 15 million cubic feet) ran to waste over the spillway after a storm had passed. A battery of ten syphons, each with an internal square section of 1·90m. (6′ 4″ by 6′ 4″) and a working head of 5·75m. (18′ 8″), was substituted to the old spillway, capable of discharging 150 cubic metres per second (5,250 cubic feet); at the same time allowing the sill to be raised by 0·95 (3 feet), by which an extra volume of 300,000 cubic metres of water (10½ million cubic feet) are impounded.

Besides, it was proved that the syphons give the discharge of 150 c.m. with only 4 inches of super-elevation of the water over the lip, or with an elevation of 14 inches less than before, when the overfall-spillway was used, thus reducing correspondingly the water-pressure against the dam.

The greater volume of 300,000 cubic metres of water thus impounded represents an income of at least 15,000 francs (600*l.*), a year, and, capitalised at 5 per cent., a total of 300,000 francs (12,000*l.*), equal to at least six times the cost of the new syphon-spillway; which, moreover, is more compact and more efficient. Of these automatic syphon-spillways there are more than 100 on Italian dams and canals, with heads varying from 3 to 20 feet, and all give complete satisfaction.

The author exhibited several views of ruins of Roman works, and a cinema-film showing the method of constructing the railway and the striking difference in the zones cultivated with and without irrigation.

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3. *Investigation of Nile River Flood Record from* A.D. 641 *to* A.D. 1451 *for Traces of Periodicity. By* T. W. Keele, *M.Inst.C.E.*

The author was led into this investigation when examining records of rainfall at various places, particularly those of the Commonwealth of Australia, with a view to ascertaining whether periodicity exists.

The results of previous study of this meteorological question were given by the author in a paper entitled 'The Great Weather Cycle,' read before the Royal Society of New South Wales on July 1, 1910, and published in their Proceedings (see volume xliv., pages 25 to 76), in which he sought to show that the period must be a long one. He was of opinion that the defects which were apparent in

the comparatively short period of nineteen years, so ably advocated by the late Mr. H. C. Russell, Government Astronomer of New South Wales, disappeared when testing multiples of that period, and that fifty-seven years more correctly represented the true period in Australia. It was, however, ascertained from a curve computed from the record of the Nile floods, which were at that time available, namely from A.D. 1736 to A.D. 1905, that the Nile's period would appear to be either 114 or 171 years.

These conclusions were based on the results arrived at by discarding the old system of plotting the rises or falls above or below an arithmetical mean of the figures constituting the record, and adopting a system which would show the *cumulative* effect of the departures from the mean. Slow, persistent rises or falls which are not discernible under the old system are immediately detected by this method.

The Nile's period then arrived at was so long that it extended far beyond the limits of all rainfall records, except, perhaps, that of British rainfall, compiled by the late Mr. Symons, F.R.S., and the Paris and Padua records, all three of which are more or less unreliable. There was consequently no means of proving its reliability or otherwise unless by comparing it with tables of historical events, which was hardly admissible in an investigation of this nature.

Fortunately the records of the height of the annual flood on the Nile from the years A.D. 641 to A.D. 1451 have recently been made available. In his letter to the author, forwarding a copy of this historical record, Mr. J. I. Craig, M.A., F.R.S.E., Director Meteorological Service, Cairo, stated that, although there is internal evidence of clerical errors in the Arabic records from which he extracted the gauge readings, on the whole he believes them to be trustworthy.

With this assurance the author computed a series of residual mass curves derived from the means of most of the periods which have been propounded from time to time. None of these were satisfactory, with the exception of the curve derived from the means of successive complete periods of 76 years, of which there are ten altogether out of the whole record of 810 years.

An inspection of the diagram will show that the conformation to a 76 years' period is very remarkable, even when this period is extended up to the present time. Notwithstanding that there are two breaks in the records from 1451 to 1825 of 285 and 25 years, respectively, the curve derived from the recent records still shows a similar conformation.

From an historical point of view the diagram is an extremely interesting one. It represents the longest continuous record in the world. The dry and wet periods are clearly defined, ranging from nineteen to fifty-seven years of accumulated rise or fall with reference to the mean.

The author was severely criticised during the discussion on his paper of July 1, 1910, previously referred to, for seeming to connect Halley's comet in some way with 'the weather.' This was because he had drawn attention to the fact that the comet's mean period was approximately 76 years, and also that its appearance seemed to occur during periods of great drought.

The position of the comet at the time of its perihelion passage is shown on the diagram on fourteen occasions from information kindly supplied by Mr. C. J. Merfield, F.R.A.S. It will be seen that in almost every instance the comet made its appearance during the periods of greatest drought in Egypt.

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4. *Imperial College of Science and Technology: The Goldsmiths' Company's Extension of the City and Guilds (Engineering) College. By* Professor W. E. DALBY, *F.R.S., M.Inst.C.E.*

This paper gave a concise history of the development of the City and Guilds (Engineering) College. The College was founded by the City and Guilds of London Institute in 1884, and its federation with the Imperial College of Science and Technology took place in 1907. In 1885 there were 35 students in attendance; last session (1912-13) there were 570.

After referring to previous extensions the paper gave a detailed account of the present engineering extension, named after the Goldsmiths' Company, who have undertaken to defray the cost of erection. This extension includes

the following laboratories on the ground floor: a top-lighted laboratory, a railway laboratory, a hydraulic laboratory, and also a boiler-room.

The top-lighted laboratory consists of four bays, having a total floor area of 17,628 square feet. The floor is of timber decking, supported on steel girders and brick columns. Underneath is a basement of equal area, in which all mains, pipes, cables, countershafts, &c., are placed. Machinery can therefore be installed without any structural alterations being made necessary. Steam is supplied from the boiler-room adjoining. A five-ton travelling crane is fitted to each bay of the laboratory.

The railway laboratory has a floor-area of 3,200 square feet. A portion of the laboratory has been designed as a wind-flume capable of producing a current of air of sixty miles per hour, the object being to ascertain the effect of wind-pressure on train-models, aeroplane-wings, and structures.

The hydraulic laboratory has a total floor-area of about 8,000 square feet. The equipment of the laboratory consists chiefly of supply tanks, measuring apparatus (including a standardising tank of 12,500 gallons capacity), weir-boxes, a west sump and an east sump (the latter having a capacity of 22,000 gallons) connected by flumes, a complete turbine plant, and two Gwynne pumps, as well as a twelve-inch Venturi meter, and mains and piping. The chief feature of the design of the laboratory is that the power to be supplied for the circulation of the water through the equipment has only to overcome the frictional resistance of a vertical lift, and is therefore at a minimum; the whole circulation can be controlled by one man standing at the pumps; and experiments with the different apparatus can take place independently and simultaneously.

The boiler-room contains two Lancashire boilers and one water-tube boiler, each capable of giving 5,000 lbs. of steam per hour, arranged so that they can be available for experimental purposes. Underneath the roadway behind the boiler-room are the coal-bunkers, capable of holding a hundred tons of coal, as well as an ash-pit from which the ashes can be hoisted through a trap-door and emptied directly into the carts.

The paper concluded with some particulars of the advanced courses in the Imperial College, showing that the objects of its founders have already been successfully carried out. The College is still rapidly developing, and will soon provide every facility for post-graduate study and research for students from all the colleges of Greater Britain.

TUESDAY, AUGUST 25.

The Section divided into two Sub-Sections, G I. and G II.

In Sub-Section G I. the following Papers were read:—

1. *The Metropolitan Electric Railways proposed for Sydney.* *By* J. J. C. Bradfield, *M.Inst.C.E.*

The paper described the proposed scheme for which Parliamentary sanction is being sought. It comprises the construction of an underground railway in the City itself, and the electrification of some of the suburban railways to connect up with the underground railway. Statistics show that the present railway and tramway systems are, or will shortly be, incapable of handling the rapidly increasing traffic. It is proposed to connect North Sydney and the City by means of a bridge across the harbour, while another bridge would connect the City with the western suburb of Balmain. It was maintained that a bridge would be cheaper than a subway, and would give better gradients and greater comfort. Since Sydney is the fifth port in the Empire, it is essential that the fairway be not impeded. For this reason the proposed harbour bridge crosses in a single span of 1,600 feet, with a headway of 170 feet above high-water. It provides for four lines of railway, beside vehicular and passenger traffic. The design and material are discussed, and a nickel-steel cantilever bridge is recommended, at an estimated cost of 2,600,000*l*. Details were given

of the proposed underground railways, location of stations, junctions, schedules, fares, &c. It is proposed to employ continuous current at 1,500 volts, supplied from overhead conductors.

A short description was given of the power station already in course of construction at White Bay, Balmain, for the tramways, which, like the railways, belong to the Government. The station will be capable of developing 100,000 h.p., and will supply the power required for the proposed railway system.

The total cost of the whole scheme is estimated at 17,000,000*l*.

2. *Australian Ports in relation to Modern Ships and Shipping.* By W. E. ADAMS, *A.M.Inst.C.E.*

The enormous increase in the size of ships trading to Australia during the last fifteen years has set a problem to the Port Authorities of Australia that calls for careful consideration. It has become very desirable to review the position not only from the standpoint of the Harbour Authorities, but also from that of the local commercial interests involved. That the civil engineer can always rise to the occasion and provide for anything the shipbuilder can produce is evidenced by such works as the Suez and Panama Canals. But, as engineering practically conceived cannot be divorced from economics, especially in a young and growing country like Australia, where much money is required for numerous lines of development, the engineer must be a rigid economist. On this account, it is advisable carefully to examine the situation that is arising in its most general aspect.

Privately-owned wharfage in the chief commercial sea-ports of Australia has almost disappeared. Public ownership of the foreshores has been rendered necessary in order that wharfage may be planned in conjunction with other great public utilities, such as railways, tramways, roads of access, and to admit of the segregation of berthage into mail and passenger, general cargo, frozen meat, grain, coal, and other specialities.

Clearly it is necessary to separate the shipment of frozen meat and grain from coal and other dirty or noxious cargoes, while passenger and mail services should berth as close to the heart of the city as possible. Where these essentials are laid out in advance contingent municipalities are enabled to co-operate to advantage, and private industries immediately connected with shipping can be established in the most suitable positions.

Thus it has come about that all the Australian capital sea-ports except Brisbane have been placed under public trusts, of various constitutions, but all aiming at the one object, namely, to provide for the shipping on a comprehensive scale, and on a self-supporting basis. In the endeavour to keep pace with shipping developments the cost of the modern sea-port has become, and promises to become in the future, a still more important commercial factor. Port-dues already amount in many cases to 10 per cent. of the freight charges.

In ocean transport three separate interests are involved. Firstly, there is the private shipowner, who invests for personal profit; secondly, the Port Authorities, who build usually to meet expenses of maintenance, interest, and sinking fund (though sometimes more is required); and thirdly, the merchant or shipper, who ships goods.

To Australia, which is a large exporter and importer, and, moreover, a country greatly in need of population, it is obviously important that oversea freights, fares, and other charges should be as low as possible, on account of the immense distance from the centre of civilisation. The point of supreme interest to Australia in this connection lies in the question as to whether modern shipping developments tend to increase or to decrease the total cost of ocean transport.

It is unquestionable that cargo and passengers can be carried more cheaply in large than in small steamers. That is, the cost per ton-mile, reckoning working expenses, including coal, wages, and upkeep, are less per ton carried in large than in small steamers. By way of illustration, Sir W. White in 1903 quoted the case of the P. and O. Company's *Moldavia*, 10,000 tons, stating that an increase in draft of three feet would increase her freight-earning

capacity by 66 per cent., while no appreciable loss of speed would ensue. This is, of course, very important to the shipowners, but the economics of ocean transport are not affected thereby unless some at least of this saving is passed on by shipowner to shipper, and ultimately to the producer. Naturally some reasonable advantage must be permitted to the shipowner, otherwise he would not build large ships, but, to place the matter on a true economic basis, it has yet to be shown that the shipper and the producer share in the saving. If not, then the big ship must rely upon other grounds of justification, and, as we shall see, these may not be lacking.

The next point for consideration is the effect of big ships upon the cost of port and harbour works to accommodate them. Conditions vary so much between the ports of Australia that the total increased outlay per berth, including the necessary dredging, could only be considered for each port in detail. Thus, at Sydney and Hobart, the matter would be practically narrowed down to the actual increased cost of the new over the old class of berth, the dredging being practically a negligible quantity; while at Melbourne and Brisbane the deepening and dredging would be heavy items. The natural physical difficulties of these two ports must, therefore, exercise a limiting influence on the size of ships trading to Australia for some time to come. Brisbane, being the only possible outlet for a vast and productive hinterland, will surely develop rapidly into a very large and important shipping centre, probably in time rivalling the southern ports.

To meet the increase in the size of ships the Port Authorities of Australia find themselves called upon to spend very large sums of money in reconstruction. Wharves and jetties that sufficed twelve or fifteen years ago are now all obsolete. Upon the cost of replacement planned on a vastly larger scale, maintenance, interest, and sinking funds have to be provided for out of the port-dues. It seems inevitable that the port-dues must tend to increase. It is not overlooked that modern appliances and large vessels will allow more cargo to be handled at a berth than formerly; but, on the other hand, when a small number of very large ships replaces a large number of small ones, berths are apt to have longer periods of idleness, and would, therefore, not be made the fullest use of.

The situation will be better understood by a comparison of the berths of fifteen years ago at the port of Sydney with those of to-day. Up to the year, say, 1900, the largest oversea vessels trading to this port averaged some 6,000 tons, and the inter-state vessels 3,000 tons. The lengths of the former ran from 430 feet to 470 feet, by 50 feet to 53 feet beam; and of the latter from 300 feet to 350 feet, by 40 feet to 46 feet beam. For vessels of this class there were a number of berths consisting of frontage wharves and jetties from 300 feet to 450 feet in length. The jetties were usually from 30 feet to 40 feet wide, and the depths of water required ranged up to 28 feet. Several of the berths having been built by private owners were without shed accommodation. The average cost per berth with cargo-sheds, inclusive of value of frontage-land, was 21,300*l*., but the same jetties built to-day at the higher prices would have cost 25,500*l*. per berth. The water-way between jetties varied from 90 feet to 110 feet, but in several cases was as little as 80 feet.

The vessels now coming to Sydney have already touched 18,400-ton mark, the largest measuring 555 feet by 69 feet, with a loaded draft of 32 feet. Clearly it is necessary to provide for much larger vessels in the future, and it would be inadvisable to look forward to anything less than a possible 1,000 feet in length, with a loaded draft of 40 feet, though these dimensions may not be reached for many years to come.

The jetties necessary to berth the oversea vessels at present trading to Sydney are from 500 feet to 650 feet in length (with provisions for extension), by 130 feet to 250 feet in width, and the water-way between them to allow for handling, coaling, and transhipping ranges from 220 feet to 360 feet. Double-decked cargo-sheds are required to accommodate the large quantities of freight rapidly put ashore, and electric cranes, gantries, and other lifting gear are being provided. The cost of these, adding the value of frontage-land, ranges from 67,000*l*. to 77,000*l*. per berth, irrespective of dredging, which, particularly in Sydney, is a small item, but in several other ports will be excessively heavy. The requirements for inter-state shipping are scarcely less. Some of

the vessels now engaged in this traffic measure as much as 9,000 and 10,000 tons, and no doubt larger ships will be built.

It seems evident, even after making allowance for the superior earning-capacity of these modern berths, that increased harbour rates will have to be charged to render such investment sound and self-supporting. This is a question that requires special investigation. Judged from a purely economical point of view, there is room for considerable doubt as to whether the advent of the large vessel has operated towards lowering the cost of sea-borne freight, including, of course, incidental charges, such as wharfage and tonnage dues, &c. The question is greatly complicated by the upward tendency of wages and materials, which not only increases the cost of ship construction, but also puts up the cost of working expenses and maintenance, which are naturally passed on by the shipowner.

There are, however, other very important considerations which must be taken into account. Pressing as the economic question is, there are distinct advantages in the employment of big ships. Higher speed can be obtained, which, at this distance from Europe, is desirable for mails, passengers, and cargo. The time-element is certainly of urgent importance to Australia. Greater safety, seaworthiness, steadiness, and comfort are also secured.

The class of wharf-construction that will come into use in the future, though important, is very uncertain at the present time. Timber has been used almost entirely in Australia. Reinforced concrete has been dealt with very charily, but it is safe to say that, if the local timbers had not proved so satisfactory from every point of view, reinforced concrete would have been largely used during the last fifteen years.

Where space is available, longshore wharves, served by low-level road and belt railway, offer the greatest facilities for handling cargo. But as this is not always possible, jetties will continue to be used to a large extent. To provide shed accommodation and low-level road access to facilitate the removal of goods, without traffic congestion, necessitates very great width of jetty. In Sydney two plans are being tried to meet such cases. In one instance the jetty is 210 feet wide, with a sunken road down the middle which brings the cart-body to the level of the shed-floor.

In another case, where the available water-frontage length is restricted, a type of jetty is being built with a high and a low side, so that when a cart is on the low side the body is at the floor-level of the higher side of the jetty. The high side, which extends over about three-quarters of the width of the jetty, will be used for inward cargo, which requires as much space as possible for sorting and stacking. The low side will be used for traffic and outward cargo, which goes aboard the ship as it arrives, and seldom accumulates on the wharf to the extent of more than four or five hundred tons at a time. These jetties will have an upper deck approached by a bridge from a high-level roadway. The upper deck will be constructed with high and low levels, similar to the lower deck, but disposed on the opposite sides. Thus, each side of the jetty will have a separate loading and unloading deck. On this account it will be possible to carry on the two operations together without confusion of outward and inward cargo, and the cost of construction will be relatively low.

The position of the other Australian ports was reviewed in the same way, for the purpose of considering how far the Port Authorities are justified in accepting the challenge of the shipowner.

3. *The Distribution of Phosphorus in Steel.* *By* WALTER ROSENHAIN, *B.A., D.Sc., F.R.S.*

The injurious influence of phosphorus on the mechanical properties of steel is very fully recognised, so much so that for a large class of important steel articles, such as tyres, axles, springs, &c., it is usual to specify that the phosphorus content shall not exceed 0·035 per cent. If phosphorus were uniformly distributed throughout steel it would be difficult to believe that less than four parts in ten thousand could exert a seriously injurious influence. Observation of all ordinary commercial steels, however, serves to show at once that phosphorus is not uniformly distributed. This matter has been studied,

chiefly by J. E. Stead, by the method of heat-tinting which differentiates between those portions of a polished steel surface rich in phosphorus and those free from it by the difference in the rate of oxidation. The banded distribution of the phosphorus thus reproduces itself as bands of different depths of tinting on the surface after exposure to heat. More recently the author and J. L. Haughton at the National Physical Laboratory have worked out a method of tracing the phosphorus distribution in steel by means of a new reagent. This is a solution of ferric chloride rendered acid by hydrochloric acid and containing in solution small quantities of the chlorides of copper and tin. When a steel surface is exposed to this reagent electro-chemical replacement occurs, a small quantity of iron passes into solution, and a corresponding amount of copper is deposited as a thin film on the surface of the steel. In an ideally pure steel this deposit would be uniform over the entire area of the ferrite constituent, but in a phosphoric steel the copper film is deposited first on those ferrite regions which are most nearly pure, those regions richest in phosphorus being left unaffected for a long time. Seen under the microscope, the surface thus 'etched' by the selective deposition of copper presents a well-defined appearance which at one point reaches a development corresponding accurately to the pattern produced by the older method of heat-tinting; at an earlier stage, however, features are shown which escape detection by the older methods. A study of these features leads the author to trace back the origin of the banded structure of phosphoric steel to processes which are known to occur in the first solidification of a 'solid solution' alloy, so that the coarser or finer banding of the finished steel depends upon the scale of crystallisation which took place in the original ingot, in spite of the fact that the crystalline structure may have been entirely changed repeatedly as the result of thermal or mechanical treatment. This great persistence of the 'geographical' distribution of phosphorus is to be ascribed to the low velocity of diffusion of iron phosphide when present in solid solution in iron. The paper was illustrated by numerous photographs and diagrams.

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4. *Notes on some Tests of Petrol Motor Fire-Engines, and the Frictional and other Resistances to the Flow of Water through Canvas Fire-Hose. By* Professor T. HUDSON BEARE, *M.Inst.C.E.*

The experiments described in this paper were carried out on two fire-engines. The first engine, supplied by Messrs. Merryweather, was driven by a four-cylinder 'Aster' petrol engine, the cylinders being 5¾ inches diameter, with a 6½-inches stroke, and the speed 1,000 revolutions per minute. The pump was of the 'Hatfield' reciprocating type, and had three single-acting plungers of 7-inches bore and 5-inches stroke; the barrels were arranged radially round a common crank-pin at an angle of 120° to one another. The pump was driven by a chain, 5½ inches wide, and was geared down 4·47 to 1; with this gearing 1,000 revolutions of the motor would correspond to 224 revolutions of the pump.

The second engine, supplied by the Halley's Industrial Motor Company, was driven by a six-cylinder petrol engine, the cylinders being 5 inches in diameter with a 5¼-inches stroke, stated to be capable of developing 60 h.p. at 1,000 revolutions per minute. The pump, made by Messrs. Mather & Platt, was of the centrifugal type, and was driven direct from the engine by enclosed gearing running in oil; the pump was geared up about 3 to 2—that is to say, when the engine was making 1,000 revolutions the pump would be making about 1,500 revolutions per minute. The engine carried a reciprocating exhauster air-pump, driven by a chain drive off the pump shaft, this mechanism being necessary in order that the centrifugal pump might be charged when drawing its water supply from a dam, or any other source in which the water was not under pressure.

Weight of Engines and Equipment.

	No. 1		No. 2	
	Tons	cwt.	Tons	cwt.
Carrying full load	5	15	4	13½
All equipment removed (except top ladder) .	4	18	4	4

Horse-power of the Engines.

	No. 1	No. 2
R.A.C. rating	52·9	60·0

The main experiments were to determine the quantity of water pumped per minute, and the pressure at the pump delivery side and at the nozzle. The quantity of water pumped was measured either by passing it through a Venturi meter on its way to the nozzle or by discharging the water from the nozzle into a big swimming-bath which had been carefully calibrated beforehand. The Venturi meter was tested for the accuracy of its records both before and after the experiments were carried out.

In order to determine frictional and other resistances to the flow of water through the canvas fire-hose, different lengths of hose were tested, all the other conditions being kept practically constant, and it was thus possible to eliminate the resistances at the point of entry into the hose, and in the meter when the water was delivered through a meter, and at the entry to the nozzle. Experiments were made with ordinary canvas hose and with rubber-lined canvas hose. The hose experimented with was 2¾ inches in internal diameter, and various diameters of nozzles were employed in the tests. The lengths of hose tested were 100 feet, 500 feet, and 1,000 feet, and some experiments were made with double lines of hose, each delivering to a nozzle of the same diameter.

The results obtained as to quantities of water pumped, pressures at pump and at nozzle, and speed of engine are given in the form of tables, and a final table gives the coefficients of frictional and other resistances to the flow of water through canvas fire-hose.

5. *Australian Timbers.* *By* Professor W. H. Warren.

In Sub-Section G II. the following Report and Papers were read :—

1. *Report on Gaseous Explosions.*—See Reports, p. 177.

2. *Temperature Cycles in Heat-Engines.* *By* Professor E. G. Coker *and* W. A. Scoble.

Experimental investigations of the cyclical variations of heat-engines and heat-pumps have received much attention, and numerous methods and instruments have been devised to give records of their cyclical changes, such as those of pressure and volume of the working fluid, changes of angular velocity of the crank-shaft, and the like. Temperature changes in the working fluid may usually be inferred very accurately from the pressures recorded on an indicator diagram, since there is usually a definite relation between pressure and temperature of a vapour, as, for example, in heat-engines using steam direct from a boiler without the intervention of a superheater. In other heat-engines, such as those using superheated fluids, and also those of the internal-combustion type, the temperature is more difficult to determine, and it becomes important to measure it directly. Platinum resistance thermometers and thermo-electric couples have been frequently employed for measuring cyclical changes of temperature in heat-engines, and a complete record from point to point of a cycle may be obtained if the engine is working with absolute uniformity. As it is usually impossible to prevent some amount of variation in the working of the engine while the measurements are in progress, the resulting curve is a composite one, since each measurement corresponds to a different cycle.

The possibility of obtaining an instantaneous automatic record with an Einthoven type of galvanometer was considered in our early experiments on the cyclical variations of temperature of the working fluid of a gas-engine, and in the walls of the cylinder, but the difficulties then appeared to be so great that a potentiometer balance method was used instead. Recently, by the kindness of the Cambridge Scientific Instrument Company, we have been able to make experiments with their latest form of short-period Einthoven galvanometer, and this has enabled us to obtain instantaneous records of the temperature-cycles of the working fluid of steam- and gas-engines, and also the variations of temperature in the walls. Some of these photographic records are shown, and

their detailed characteristics are considered in the paper. They confirm the general accuracy of our former measurements on cyclical variations of temperature in a gas-engine cylinder, and also show some new features due to variations from stroke to stroke caused by misfires and the like.

3. *The Lost Pressure in Gaseous Explosions.* *By* Professor W. M. Thornton, *D.Sc.*, *D.Eng.*

When the maximum pressure of an explosion is calculated from the heat of combustion of the elements of the gaseous mixture values are obtained which are in all cases about twice those found by experiment. The mean of a large number of 'efficiencies of explosion' for different combustible gases approaches one-half. To account for this four chief suggestions have been made: (1) that there is dissociation of the products of combustion; (2) that the specific heats are much higher at explosion temperatures; (3) that the products are rapidly cooled by radiation to the walls of the vessel; (4) that the combustion is not complete at the time of reaching the maximum pressure. None of these is in itself sufficient to account for all the loss of pressure. The suggestion is now made that it may be caused by the forces of cohesion which come suddenly into play at the moment of formation of a molecule, check the translational energy to which alone pressure and temperature are due, and raise for the moment the rotational energy of the combining bodies. It is shown that the ratio of the translational energy of two colliding and cohering bodies before and after collision is one-half, and this ratio is to be expected for the whole mixture.

The suggestion receives support from the form of the curve connecting efficiency of explosion and changed percentage of gas in the mixture. This efficiency can be shown to have the form $\mu=1-BN$, where B is a constant and N is the number of combustible units in unit volume. A combustible unit is defined as that group of one molecule of combustible gas and of oxygen atoms just sufficient for its complete combustion. At the upper limit N is zero, and the efficiency curve is triangular on a base coinciding with the limits of inflammability. Its mean height is therefore one-half of the maximum, and this agrees very fairly well with the observed values given by Clerk in the case of coal-gas.

4. *The Limiting Conditions for the Safe Use of Electricity in Coal Mining.*[1] *By* Professor W. M. Thornton, *D.Sc.*, *D.Eng.*

The paper was a summary of recent researches on the limits of electrical ignition of inflammable mine-gases and coal-dust. The lower limit of inflammability is 5·6 per cent. of methane in air by volume; a temperature of 200° C. lowers this to 5·1 per cent. The most inflammable mixtures are at 8 per cent. for continuous-current break-sparks, 10·2 per cent. for alternating-current breaks. Excess of nitrogen appears to markedly increase the necessary igniting current. With non-inductive circuits 1 ampère at 100 continuous volts is a typical value; the corresponding values with alternating current are 7 ampères at 40 periods a second, 16 at 60, 20 at 80, and 29 at 100. By varying the inductance the energy of an igniting break-spark is found to be constant at about 0·1 joule. Electric signalling bells have inductance up to 0·5 henry and ignite gases at the trembler spark or signalling point. All electric lamps and fuses, however small, must be enclosed. Oscillations on a cable sheath caused by short circuits on the conductor will not ignite gas, but maintained leakage arcs from armouring are only slightly more active than break-sparks. Static discharges from 6-inch high-speed belting could not be made to ignite gas, nor the blue brush discharge from high-pressure conductors. Movements of clouds of dust have been shown to give electrification and to cause sparks, but the energy must be much greater than can be obtained experimentally in order that this should become dangerous. Wireless telegraphy operations on the surface do not induce sparking potentials underground. Capacity sparks in general from cables left insulated after being charged are very active, 0·002

[1] Published in the *Electrician*, lxxiii., p. 822.

to 0·005 joule causing ignition. The influence of gas in forwarding coal-dust explosions begins to be felt when ½ per cent. of gas is present. At 2 per cent. full ignitions are obtained at every trial. Coal-dust alone can be ignited by both continuous-current or alternating-current break-flashes, the former requiring 3·5 to 6 ampères at 480 volts in non-inductive circuits, the latter 14 ampères at 40 periods and on a power factor of 0·8. Continuous-current faults on the negative cable develop rapidly in the presence of moisture and the cable is disintegrated. Alternating-current faults are self-healing, and a mechanical fault does not increase electrically on an alternating-current cable.

Armouring is necessary under modern power conditions; lighting and signalling circuits must be equally well protected to prevent open sparking. The limits of safety are electrically low, but the risks of ignition are even now no greater than those attending the use of flame safety lamps, and they can be entirely prevented.

5. *The Balsillie System of Wireless Telegraphy as employed in the Radio-Telegraph Stations of the Commonwealth of Australia.*[1] *By* J. G. Balsillie.

6. *The Capacity of Radio-Telegraphic Aerials.*[2] *By* Professor G. W. O. Howe, *D.Sc.*

The capacity considered in this paper is the actual static capacity, and not the equivalent capacity of the antenna considered as part of an oscillatory circuit. The accurate calculation of the capacity of a multiple-wire horizontal aerial with its leading-down wires would be a difficult mathematical problem, quite unwarranted by the practical requirements of radio-telegraphy.

When raised to a potential above or below that of the earth, the charge is distributed over the antenna in a way which is not easy to calculate, but which must be such that all parts of the antenna are at the same potential. If the antenna were made up of a great number of short pieces, placed end to end, but insulated from each other, it would be possible to distribute the charge uniformly, but the potential would then vary from point to point in a way which is easily calculated. If now we assume that all the separate pieces of wire are connected, electricity will flow from points of high to points of low potential until the potential is everywhere the same. The assumption made in developing the various formulæ is that this final uniform potential is equal to the average value of the potential when the charge was uniformly distributed. This is only approximately correct, but the accuracy is more than sufficient for all practical purposes. This method has been applied to antennæ of all the types usually employed, and formulæ have been established for each type. A large number of numerical examples have been worked out, and the results are given in tables and curves, so that the capacity of any antenna can be read off directly from its dimensions. The corrections due to the leading down wires and to the proximity of the earth are fully considered, and examples given showing the application of the formulæ to antennæ of any type.

Formulæ for the calculation of the capacity of antennæ have recently been published by Pedersen ('Jahrbuch der Drahtlosen Telegraphie,' vii. 4, p. 434) and Louis Cohen (*Electrician*, February 14 and 21, 1913). When applied to the experimental results quoted by Cohen, the formulæ developed in this paper give closer agreement than do the formulæ given by Cohen, although some of his results can hardly be reconciled with the given data.

7. *Irrigation Dams and Hydro-Electric Power.*[3] *By* E. Kilburn Scott.

[1] Published in the *Electrician*, lxxiv., p. 70.
[2] Published in the *Electrician*, lxxiii., p. 829.
[3] Published in *Electrical Review*, lxxv., p 317.

Section H.—ANTHROPOLOGY.

President of the Section.—Sir Everard im Thurn, C.B., K.C.M.G.

The President delivered the following Address at Sydney, on Friday, August 21:—

A Study of Primitive Character.

Civilisation and 'savagery'—for unfortunately it seems now too late to substitute any term of less misleading suggestion for that word 'savagery'—are the labels which we civilised folk apply respectively to two forms of human culture apparently so unlike that it is hard to conceive that they had a common origin—our own culture and that other, the most primitive form of human culture, from which, at some unknown and distant period, our own diverged. But, assuming one common origin for the whole human race, we anthropologists can but assume that at an early stage in the history of that race some new idea was implanted in a part of these folk, that is in the ancestors of civilised folk, which caused these thenceforth to advance continuously, doubtless by many again subsequently diverging and often intercrossing roads, some doubtless more rapidly than others, but all mainly towards that which is called civilisation, while those others, those whom we call 'savages,' were left behind at that first parting of the ways, to stumble blindly, advancing indeed after a fashion of their own, but comparatively slowly and in a quite different direction.

It is easy enough for civilised folk, when after age-long separation they again come across the 'savages,' to discern the existence of wide differences between the two, in physical and mental characteristics, and in arts and crafts; it is not so easy, it may even be that it is impossible, to detect the exact nature of these differences, especially in the matter of mental characters.

As a rule the occupant of this presidential chair is one who, whether he has seen much of 'savages' at close quarters or not, has had much ampler opportunity than has fallen to my lot of comparative study of that great mass of anthropological observations which, gathered from almost every part of the world, has now been recorded at headquarters. I, on the other hand, happen to have spent the better part of my active life in two different parts of the world, remote from books and men of science, but in both of which folk of civilised and of savage culture have been more or less intermixed, but as yet very imperfectly combined, and in both of which I have been brought into rather unusually close and sympathetic contact with folk who, whatever veneer of civilisation may have been put upon them, are in the thoughts which lie at the back of their minds and in character still almost as when their ancestors were at the stage of savage culture.

While trying to adjust the mutual relations of wild folk and of folk of civilised stock, I have seen from close at hand the clash which is inevitable when the two meet—a clash which is naturally all the greater when the meeting is sudden. Moreover, having started with a strong taste for natural history, and especially for the natural history of man, and having had much guidance from many anthropological friends and from books, I have perhaps been especially fortunate in opportunity for studying the more natural human animal at close quarters and in his natural surroundings. I have tried, from as abstract and

unprejudiced a point of view as possible, to understand the character, the mental and moral attitude, of the natural 'savage' as he must have been when civilised folk first found him and, at first without much effort to understand him, tried abruptly to impose an extremely different and alien form of culture on this almost new kind of man.

I venture to claim, though with diffidence, that I may have begun to discern more clearly, even though only a little more clearly than usual, what the primitive man, the natural 'savage'—or, as he might more accurately be described, the wild man—was like; and it seemed possible that an attempt to bring together a picture—it can hardly be more than a sketch—of the mentality and character of some one group of people who had never passed out of the stage of 'savagery' might be interesting and practically useful, especially if it proves possible to disentangle the more primitive ideas of such people from those which they subsequently absorbed by contact, at first with other wild, but less wild, folk, and later with civilised folk; and that a further study of the retention by these folk of some of their earlier habits of thought during later stages in their mental development might suggest a probable explanation of certain of their manners and customs for which it is otherwise hard to account.

The attainment of some such understanding is, or should be, one of the chief objectives of the practical anthropologist, not merely for academic purposes, but also for the practical guidance of those who in so many parts of our Empire are brought into daily contact with so-called 'savages.'

Perhaps hardly anywhere else in the world would it be possible to find better opportunity and more suitable conditions for such a study as I now propose than in the tropical islands of the South Seas. The ancestors of these islanders, while still in purely 'savage' condition, must have drifted away from the rest of the human race, and entered into the utter seclusion of that largest of oceans, the Pacific, covering as it does more than a third of the surface of the globe, long before the first man of civilised race, Balboa, in 1513, from the Peak in Darien, set eyes on the edge of what he called 'the Great South Sea,' before Magellan, in 1520, forced his way into and across that same sea, which he called the Pacific, and certainly long before civilised men settled on any part of the shore of that ocean, *i.e.*, in 1788, at the foundation of Australia. For when first studied at close quarters by civilised folk from Europe, which was not till after the last-named event, these South Sea 'savages' had been in seclusion during a period sufficiently long—and certainly no short period would have sufficed for such an effect—not only for them all to have assumed characters, cultural and even physical, sufficient to distinguish them from all other folk outside the Pacific, but also for them to have split up into many separate parties, probably sometimes of but few individuals, many of which had drifted to some isolated island or island-group, and had there in the course of time taken on further well-marked secondary differences.

It will probably now never be discovered when, how often, and from what different places the ancestors of these folk reached the Pacific. It is quite possible that they entered again and again, and were carried by winds and currents, some from west to east and some in the reverse direction, many perishing in that waste of waters, but some reaching land and finding shelter on some of that great cloud of small islands which lie scattered on both sides of the equator and nearly across that otherwise landless ocean.

Of the folk who in those old times thus drifted about and across the Pacific, the most important, for the part which they played in the story which I am endeavouring to tell, were the two hordes of 'savages' now known respectively as Melanesians and Polynesians. Without entering deeply into the difficult subject of the earlier migrations of these two hordes, it will suffice here to note that, towards the end of the eighteenth century, when European folk at last began to frequent the South Sea Islands, and when consequently something definite began to be known in Europe about the islanders, certain Melanesians, who had probably long previously drifted down from north-westward, were found to be, and probably had long been, in occupation of the exceptionally remote and isolated Fiji Islands; also that, long after this Melanesian occupation of these islands, and only shortly before Europeans began to frequent them, several bodies of Polynesians, who had long been in occupation of the Friendly

or Tongan Islands, lying away to the east of Fiji, had already forced or were forcing their way into the Fijian Islands.

The meeting in Fiji of these two folk, both still in a state of 'savagery,' but the Polynesians much further advanced in culture than the Melanesians, at a time before European influence had begun to strengthen in those islands, affords an exceptionally good opportunity for the study of successive stages in the development of primitive character, especially as the two sets of 'savages' were not yet so closely intermingled as to be indistinguishable—at least in many parts of Fiji. It is unfortunate that the earliest European visitors to Fiji were not of the kind to observe and to leave proper records of their observations.

The earlier, Melanesian, occupants of Fiji had to some extent given way, but by no means readily and completely, to the Polynesian invaders. The former, not only in the mountain fastnesses difficult of access, but also in such of the islets as the local wind and weather conditions made difficult of access, retained their own distinct and simpler culture, their own thoughts, habits, and arts, long after the Polynesians had seized the more important places accessible to the sea, and had imposed much of their own more elaborate (but still 'savage') culture on such of the Melanesians' communities as they had there subjugated and absorbed.

The social organisation throughout Fiji remained communistic; but in the purely Melanesian communities the system was purely democratic (*i.e.*, without chiefs), while in the newer mixed Polynesian-Melanesian communities—as was natural when there had been intermingling of two unequally cultured races—there had been developed a sort of oligarchic system, in which the Melanesian commoners worked contentedly, or at least with characteristic resignation, for their new Polynesian chiefs.

Alike in all these communities custom enforced by club-law prevailed; but in the one case the administrative function rested with the community as a whole, while in the other it was usurped by the chiefs.

Though we are here to consider mainly the ideas, the mentality, of these people, it will be useful to say a few preliminary words as to their arts and crafts. The Melanesians during their long undisturbed occupation of the islands had undoubtedly made great progress, on lines peculiar to them, especially in boat building, in which they excelled all other South Sea islanders, in the making of clubs and other weapons, and in otherwise using the timber, which grew more abundantly, and of better quality, in their islands than elsewhere. Meanwhile the Polynesians, in their earlier homes and long before they reached Fiji, had developed, in very high degree, corresponding but different and much more elaborate arts (and ideas) of their own. But, as we know from Captain Cook, the Polynesians, despite their own higher culture, from their Tongan homes, greatly admired and appreciated the special craftsmanship of the Fijians, and it was indeed this admiration which attracted the former from Tonga to Fiji; and when the Polynesians had gained footing in the Fijis they—quite in accordance with human nature—were inclined, for a time at least, to foster the foreign Fijian arts—if not Fijian ideas—rather than replace these by their own arts; and before the struggle, both physical and cultural, between the two sets of 'savages' had gone far it was interrupted, and more or less definitely arrested, by the arrival and gradual settlement of the still more powerful, because civilised, white folk from the Western world.

In turning to the earlier (Melanesian) occupants of Fiji, and especially to the less advanced of these, to find the traces of which we are in search of the more primitive habit of thought, it must not be forgotten that even at the stage at which we begin to know about them they had made considerable advance, in their ideas as well as in their arts and crafts. They still used their most primitive form of club, but also made others of much more elaborated form; so, though the ideas which lay at the basis of their habit of thought were of very primitive kind, they had acquired others of more complex character.

Before going further may I say—and I sincerely hope that the suggestion will not be misunderstood—that in the difficult task of forming a clear conception of the fundamental stock of thought which must have guided the conduct of the more primitive folk we must constantly bear in mind the parallelism (I do not mean necessary identity of origin) between the thoughts of the earliest human folk and

the corresponding instincts (as these are called) noticeable in the case of some of the higher animals? I am particularly anxious not to be misunderstood; the suggestion is not that even the most primitive human folk were mentally merely on a par even with the higher animals, but that many, perhaps most, of the ways of thought that guided the primitive man in his bearing towards the world outside himself may be more easily understood if it is once realised, and afterwards remembered, that the two mental habits, however different in origin and in degree of development, were remarkably analogous in kind.

A similar analogy, in respect not of thoughts but of arts, may well illustrate this correspondence between the elementary ideas of men and animals. The higher apes occasionally arm themselves by tearing a young tree up by the roots and using the 'club' thus provided as a weapon of offence and defence against their enemies. Some of the primitive South Sea islanders did—nay, do—exactly the same, or at any rate did so till very lately. The club—the so-called *malumu*—which the Fijian, then and up to the much later time when he ceased to use a club at all, greatly preferred to use for all serious fighting purposes was provided in exactly the same way, *i.e.*, by dragging a young tree from the ground, and smoothing off the more rugged roots to form what the American might call the business end of the club. But though the Fijian, throughout the period during which he retained his own ways, used and even preferred this earliest form of club, he meanwhile employed his leisure (which was abundant), his fancy, and his ingenuity, in ornamenting this weapon, and also in gradually adapting it to more and more special purposes, some of the later of which were not even warlike but were ceremonial purposes, till in course of time each isolated island or group of islands evolved clubs special to it in form, purpose, and ornament, and the very numerous and puzzlingly varied series of elaborate and beautiful clubs and club-shaped implements resulted. It seems to be in power of improvement and elaboration that lies the difference between men-folk and animal-folk.

Something similar may be assumed to have brought about the evolution of the ideas of these islanders. Starting with a stock of thoughts similar in kind to the instincts of the more advanced animals, the human-folk—by virtue of some mysterious potentiality—gradually adapted these to meet the special circumstances of their own surroundings, and in so doing ornamenting these primitive thoughts further in accordance with fancy.

In the Fiji Islands this process of cultural development was probably slow during the long period while the Melanesians, with perhaps the occasional stimulus afforded by the drifting in of a little human flotsam and jetsam from other still more primitive folk, were in sole occupation; yet it must have been during this period and by these folk that the distinctively Fijian form of culture was evolved. But the process must have been greatly accelerated, and at the same time more or less changed in direction, by the incoming of the distinct and higher Polynesian culture, at a time certainly before, but perhaps not very long before, the encroachment of Europeans.

In order to realise as vividly as possible what were the earlier, most elementary, thoughts on which the whole detail of his subsequent 'savage' mentality was gradually imposed, it is essential for the time being to discard practically all the ideas which, since the road to civilisation parted from that on which savagery was left to linger, have built up the mentality of civilised folk; it is essential to try to see as the most primitive Fijian saw and to conceive what these islanders thought as to themselves and as to the world in which they found themselves.

It seems safe to assume that the primitive man, absolutely self-centred, had hardly begun to puzzle out any explanation even of his own nature, still less of the real nature of all the other beings of which he must have been vaguely conscious in the world outside himself. To put it bluntly, he took things very much as they came, and had hardly begun to ask questions.

He was—he could not but be, as the lower animals are—in some vague way conscious of himself, and from that one entirely self-centred position he could not but perceive from time to time that other beings, more or less like himself, were about him, and came more or less in contact with him.

The place in which he was conscious of being appeared to him limitless. He did not realise that he could move about only in the islet which was his

home, or perhaps even only in a part of a somewhat larger, but according to our ideas still small, island; if other islets were in sight from that on which he lived, these also would be part of his world, especially if—though such incidents must have been rare—he had crossed to, or been visited by strangers from, those islands—islands which lay between his own home and that which he spoke of as *wai-langi-lala* (water-sky-emptiness) and we speak of as the horizon. To him the world was not limited by any line, even the furthest which his sight disclosed to him. Rarely, but still sometimes, strangers had come from beyond that line. Perhaps too he had some time heard that his ancestors had come from the somewhere which seemed beyond. Again his ancestors of whom he had heard, and even some of the contemporaries whom he had seen, though no longer with him except occasionally during his dreams in bodily form, were somewhere, somewhere beyond that line of sight. Even he himself (in what were his dreams, as we say, but to him were part of his real life) habitually went beyond the line, and, as far as his experience had gone, returned each time to the island home.

Moreover, he did not doubt that this limitless region in which it vaguely seemed to him that he, and innumerable other beings, moved, extended not merely along what we speak of as the surface of the globe, but also, and equally without any intervening obstacle, up into the infinite space above and beyond the sky. In short, to this primitive man the world, though the part of it to which he had actual access was so small, was limitless.

The thoughts of the dweller in this vague world, as to himself and as to the other beings of which from time to time he became conscious, must have been correspondingly indefinite.

He was, to a degree almost if not quite beyond our power of conception, a spiritualist rather than a materialist; and it is essential to get some idea of the extent and manner of his recognition of spiritual beings—and his corresponding non-recognition of things material.

In passing I here disclaim, for myself at least, the use of the misleading word 'belief' in speaking of the ideas of really primitive man—as, for instance, in the phrase the 'belief in immortality.' Possibly primitive men of somewhat more advanced thought, though not yet beyond the stage of 'savagery,' may have 'believed' in spirits, in immortality, and so on; but it seems to me that at the earlier stage there can hardly have been more than recognition (admittedly very strong recognition) of spiritual beings, and non-recognition of any beginning or ending of these spirits.

To return from this digression, Sir E. B. Tylor long since gave currency to the very useful word 'animism' as meaning 'the belief in spiritual beings,' and this has been taken to mean that animism was the initial stage, or at any rate the earliest discoverable stage, of all religion. The primitive Fijian was certainly a thorough-going animist, if his extraordinarily strong but vague recognition of spiritual beings suffices to make him that; but I do not think that the ideas of that kind of the primitive 'savage'—or, say, of the most primitive Fijian—before his ideas had been worked up into somewhat higher thought, during the long period while he was secluded in his remote islands and before the advent of the Polynesians, had developed far enough to constitute anything which could be called 'religion,' though doubtless they were the sort of stuff which, had these folk been left to themselves, might, probably did, form the basis of the 'religion' towards which they were tending.

Practically all human beings—savage and civilised alike—and, though in lower degree, even animal-folk, have in some degree recognised the existence of some sort of spiritual beings. The point then seems to be to discover what was the nature of the spiritual beings which the primitive Fijian recognised but without understanding.

Anthropologists have recently defined, or at least described, several kinds of spiritual beings as recognised (even here I will not use the word 'believed') by more or less primitive folk. There is, first, the soul, or the separable personality of the living man or other being; secondly, the ghost, or the same thing after death; thirdly, the spirit, which is said to be a soul-like being which has never been associated with a human or animal body; and, fourthly, there is, it appears, to be taken into consideration yet another kind of spiritual being

(or something of that nature) which is the life of personality, not amounting to a separable or apparitional soul, which, it has been supposed, some primitive folk have attributed to what we call 'inanimate things.'

It seems, though I say this with all due deference, that this identification and naming of various kinds of spiritual beings, though it may hold good of animism at a higher stage, does not fit the case of the more primitive animist (say, that of the Melanesian in the very backward state in which, as far as we know, he first reached Fiji), for presumably he had not as yet recognised nor differentiated between the various kinds just enumerated. He recognised something which may be called the 'soul,' which was the separable personality of the living man or other being. But he did not recognise—perhaps it would be better to say that he had not yet attained to recognition of—the ghost, or the same thing after death; for he had not even recognised any real break, involving change, at death. Nor, as I think, did he recognise a spirit, *i.e.*, a soul-like being which had never been associated with a human or animal body; for he had no idea of any spiritual being which did not, or could not, on occasion associate itself with a human, animal, or other material body, nor seemingly had he reached the stage, labelled *animatism*, in which he would have attributed life and personality to things (which I take to mean things which are to us inanimate).

All that the most primitive man would recognise would be that he himself—the essential part of him—was a being (for convenience and for want of a better name it may be called 'soul') temporarily separable at any time from the material body in which it happened to be, and untrammelled—except to some extent by the clog of the body—by any such conditions as time and space; he had found no reason to think that in these respects the many other beings of which from time to time he became aware (whether these were what we should class as men, other animals, or the things which we speak of as inanimate, such as stocks and stones, or bodiless natural phenomena, such as winds) differed from himself only in the comparatively unimportant matter of bodily form; moreover, it seemed to him that, as he himself could to some extent do all these, the other beings, and some perhaps even more easily, were able to pass from one body to another.

He felt that these 'souls' were only temporarily and more or less loosely attached to the particular material forms in which they happened to manifest themselves at any moment, and that the material form in which the soul (and noticeably this held good even of his own soul) happened at any moment to be embodied was of little or no real importance to that soul, which could continue to exist just as well without as with that body.

Another point which it is important to note is the egoism of the savage man as distinguished from the altruism of the civilised man; for it was perhaps the beginning of the idea of altruism, of duty to one's neighbour, that gave the start to civilisation, and it was because the ancestors of the savage had never got hold of this fundamental principle of altruism that they were left behind.

The uncivilised man, complete egoist as he was, thought and acted only for his own personal interests. It is true that he was to a certain extent kind (as we might call it) to the people of his own small community, and possibly still more kind to such of the community as seemed to him more immediately of his own kindred. But this kindness was little more than instinctive—little more than a way of attracting further service. It is also true that on the occasions, which must have been very rare till a late period in the Melanesian occupation of Fiji, when strangers—*i.e.*, persons of whom he had not even dreamed—came, so surprisingly, into his purview, he was sometimes civil or even hospitable to those strangers (it should not be forgotten that to him these were souls embodied by separable accident in material forms); but this would have been only on occasions on which he knew, or suspected, that these visitors were stronger than himself and able to injure or benefit him.

Another point of great significance in the character of this primitive man was that he had no conception of ownership of property. To him all that we should class as goods and chattels, his land, or even his own body, was his only so long as he could retain it. He might if he could and would take any such property from another entirely without impropriety; nor would he resist, or even

wish to resist, the taking from himself of any such property by any one who could and would take it.

Again, the primitive man must have been far less sensitive to pain, and far less subject to fear, than the normal civilised man. I do not mean that the primitive Fijian was without the ordinary animal shrinking from physical pain, but that he cannot have been nearly as sensitive even to physical pain as is the more sophisticated man; nor had he the same mental pain, the same anticipation and fear of pain, that the civilised man has.

Having thus dealt with some of the more important points in the character of the primitive Fijian, I propose next to consider how far these suffice to account for some of the more 'savage' conditions under which these islanders when first seen were living.

Cannibalism claims the first mention, in that, though the practice has been recorded from many other parts of the world, it is commonly supposed to have been carried further in Fiji than elsewhere.

Here, however, it is at once necessary to point out that the outbreak of cannibalism in Fiji in the first half of the last century was not due to any innate and depraved taste on the part of the Fijians, and that the practice to the degree and after the fashion of which the story-books tell was not natural to the Fijian, whether of Melanesian or Polynesian stock.

It is probable, even perhaps certain, that all the Fiji islanders occasionally ate human flesh before the coming of white men to the islands; but it was only after the arrival of the new-comers that this practice, formerly only occasional and hardly more than ceremonial, developed into the abominable orgies of the first half of the last century. The first Europeans to set foot—about 1800—and to remain in the islands for any time were the so-called 'beachcombers.' At first at least, these renegades from civilisation, to secure their own precarious position and safety, contrived to put themselves under the patronage of some one or other of the great native chiefs, who would be Polynesians, and assisted and egged on these chiefs in their then main occupation of fighting other great rival chiefs, also Polynesians, and raiding the less advanced Melanesians of the surrounding districts. The guns and ammunition which the beachcombers, in some cases at least, brought with them or managed to procure, and the superior craft which they had imbibed from civilisation, greatly assisted them in this immoral purpose. Consequently a habit of cruelty, new to the Fijian, was implanted and developed, especially in the Polynesian chiefs. It became more and more a fashion for the greatest native warriors, thus egged on, to vie with each other in the number of their victims and in the reckless cruelty with which these were killed. Doubtless at first the victims were opponents killed in fight, sometimes great rival chiefs and sometimes mere *hoi polloi* who had been led out to fight, probably not very reluctantly, for their chiefs. Incidentally more and more people were killed; and the bodies of the slain were conveniently disposed of in the ovens. A taste for this food was thus developed in the chiefs—though this seems, for a time at least, to have been confined to the great chiefs, most of those of lower status, and all women, refusing to partake, at any rate till a later period. Before long, when the number of the killed ran short, the deficiency was made up by clubbing more and more even of their own people, till eventually the great native warrior took pride in the mere number of those he had killed and eaten.

It seems probable that even the coming of the missionaries, who first reached Fiji thirty or forty years after the earliest beachcombers, and at once began almost heroic efforts to stop cannibalism, thereby to some extent temporarily even aggravated the evil. For the chiefs, in their characteristic temper of gasconade, killed and ate more and more unrestrainedly, in mockery of the missionaries and to show what fine fellows they thought themselves to be.

To return from this digression into a somewhat distasteful subject, cannibalism as practised by the Fijians before the coming of white men was very different, and, from the Fijian point of view—if I may say so without fear of being misunderstood—not altogether indefensible. It must be remembered that there was, as it were, no killing in our sense of the word involved, merely a setting free from the non-essential body of the essential soul, which soul survived just as well without the body as with it.

Note that the soul must have been considered as in some way and for a time still associated with its late body if, as is commonly and perhaps rightly held, the slayer sometimes ate some part of the body of the slain in order to acquire some of the qualities of the slain.

Again, there can be little doubt that men were sometimes killed for sacrificial purposes, the material bodies of the victims being placed at some spot (perhaps the tomb) considered to be frequented by the disembodied spirit of some ancestor for whom it was desired to provide a spirit attendant. It may be noted that this sacrificial use of the body might be combined with an eating of the same body when once it had served its first purpose of attributing the spirit which had been in it to the service of the honoured ancestor.

It has been laid to the charge of the Fijians (as to that of many other folk of savage and even of civilised culture) that they habitually killed strangers, especially such as had been washed or drifted to the islands by the sea—who, in early times at least, must have been almost the only strangers to arrive. The charge, like that of cannibalism, has been exaggerated, and the facts—as far as there were any—on which this charge was founded have been misunderstood.

Here, again, the attitude of the Fijian in this respect was hardly different from that of the lower animals under similar circumstances. The Fijian knew of no reason to be glad of the arrival of strangers, unless these could, in one way or another, be useful to him; and, as has already been explained, he knew of no reason why he should not make the best use possible of the stranger, of his body or his spirit, separately or together.

While, as must have been the case in earlier times, the new-comers were dark-skinned men like himself, the Fijian might without the slightest prick of conscience separate their bodies from their spirits, and dispose of the body or the spirit separately; or without effecting this separation, he might simply enslave the new-comers; or, again, if he suspected that the new-comers were too strong for him, he might yield himself to them as a slave.

And later, when Europeans began to arrive, sometimes as refugees from passing ships and sometimes as survivors from ships wrecked on the surrounding reefs, the bearing of the Fijian towards this new kind of stranger would have been on the same principles, only that in this case the new-comers, being of far less readily understood kind, would be regarded with more suspicion and also more respect. I believe that very seldom, if ever, was an inoffensive white man, wrecked sailor or other, killed, or treated with anything but kindliness and courtesy, even though the wrecked man's property might naturally be appropriated by the natives. It was only when white-skinned strangers became commoner, and frequently more offensive, and when familiarity had bred contempt, that they were killed, as nuisances, and, especially during the great outbreak of cannibalism, were eaten.

This point in the bearing of the islanders to white men might be further illustrated by a circumstance which, to my surprise, I have never found mentioned, *i.e.*, that during the whole period while the missionaries were, with a rashness only justified by the circumstances, testifying against the natives in Fiji not one of these was killed, till at a much later period, when European influence was all but predominant in Fiji, Baker was killed and eaten under very special circumstances.

If it were possible to ascertain in each case the facts as to the reception by 'savages' of the first white men they saw, it would almost certainly be found that the reception was apparently kindly, though this kindness may really have been due to fear and not to charity. It was, however, quite probable that at any moment the savage might find that his dread of the white man was unfounded, and in that case he might kill him (*i.e.*, separate his soul from his body) without hesitation, and after doing this his fear—he probably never had any affection for him—of the disembodied spirit of the white man might be as great, or even greater, than before.

Incidentally it may here be noted, as a further curious point, that a Fijian who thus quite remorselessly set free the soul of a stranger from its body would probably not often and not for long in his dreams be revisited by his victim, if a native; and perhaps not even if the victim were a white man, unless very

remarkable. In other words, the victim survives only just so long as he is remembered. Captain Cook, we know, survived for very long, perhaps does so still; few, if any, of such beachcombers as were later killed in Fiji survived for any length of time; and the innumerable natives who were drifted or washed to one or other of the islands must for the most part have passed from memory soon after they were killed.

It has been suggested that the killing of strangers may have been for the purpose of preventing the introduction of disease; and it is certain that, perhaps even before the coming of white men, the islanders recognised that the advent of strangers was curiously often and most disastrously followed by the introduction of new diseases, either real diseases or at least some queer, unexplained influence which has so often made life not worth living for savages where white strangers have been.

The Fijians were hardly more notorious for cannibalism than for theft—and almost as undeservedly. There is hardly an account of the visit of a European ship in early times to any of the islands which does not mention that the islanders who came aboard took whatever they fancied, either quite openly or if furtively then without evincing anything like shame when discovered. This habit, which the explorers naturally called theft, was but the manifestation of a South Sea custom, due to the entire absence of any idea of personal property, which in Fiji is called keri-keri. To keri-keri was to take whatever you wanted and could take without the previous holder of the property preventing you. In old days no Fijian doubted his own absolute right to keri-keri, nor did he feel the very slightest shame in thus (as we should say) 'depriving another of his property' or 'stealing'; and even to this day the Fijian, provided that he is not really Europeanised, will keri-keri without shame. In short the idea of ownership and individual property never occurred to the natural Fijian. He took what he wanted, and was strong enough to take. But, on the other hand, he yielded up, practically without reluctance, whatever another stronger or cleverer than himself wanted and was able to take from him.

Of the many other charges of 'savagery' made against Fijians, I can, in the time at my disposal, deal with but one more, that as to their strange and gruesome habit of celebrating great occasions by killing their own folk. When a Fijian chief died, as we should say, or, as it seemed to the surviving natives, when his soul left the body which it had for a time used, his widows, and other of his kindred and dependents, unwilling to be left behind, were strangled, often indeed helped to strangle themselves, that their bodies might be put into the graves, while their souls went gladly with that of the chief whom they had been accustomed to follow.

Again, when a chief built a house, some of his dependents, whom the great man told off for the purpose, willingly stepped down into the holes which had been dug for the house-posts, and remained there while the earth was filled in on to them, and continued thereafter as permanent supporters of the house.

Again, there is a tradition, which at least was not incredible to the natives, that a great chief one day went a-fishing, and caught many fish. Two brothers of humbler rank who happened to have come down to the same waterside, also to fish, were less successful. The chief, in a characteristic freak of generosity, presented his best fish to the elder of the two brothers, who, strictly according to Fijian custom, accepted the gift, but felt bound to make an immediate return, but he had nothing to give. Thereupon the younger brother, at his own suggestion, was clubbed by the elder, and his body presented to the chief in token that his soul would thereafter serve that chief.

It is even said that when yams and other vegetables were brought in as food for the chiefs by the dependents who had grown them for that purpose, the food-bearers, if there was a scarcity of fish or other suitable accompaniment for the vegetable diet, were themselves clubbed and their bodies eaten. This particular atrocity probably happened only after the habit of cannibalism had, as already explained, been unnaturally intensified. But the story is noteworthy in that the food-bearers are not represented as in any way dreading or shirking the use to which their bodies were put.

In all these and similar cases it is to be noted that the victims (as we are naturally inclined to call them) were more or less indifferent, if indeed they

were not eagerly consenting parties, to the use (cruel as it seems to us) made of their material bodies. Thus the widows were eager to be strangled, and often even helped to do the deed, in order that they—all that was essential of them, *i.e.*, their souls—should rejoin the deceased. Similarly those others who were killed on the occasion of the funeral were quite willing to give their bodies, which seemed of comparatively little importance, as 'grass' to be added to the cut fern and other soft material on which the body of the deceased chief was couched in the grave; and quite willingly the men told off for that purpose stepped down into the holes in which the house-posts were grounded, that they, or rather their bodies, might thereafter hold up the house, while their souls enjoyed life much as before but without the encumbrance of the body. Others again contentedly grew *taro* for the chiefs to eat, and carried it in when ripe, thinking it of little importance that their mere bodies might be eaten with the *taro*.

In conclusion, having endeavoured to realise for myself, and to show you a glimpse, of the enormous, hardly conceivable difference in habit of thought, and consequently in character, which separates the savage from the civilised man, I will offer a suggestion which seems to me possibly the most important outcome of my personal experience, now closed, as an anthropological administrator in tropical places where Eastern and Western folk have met, and where the inevitable clash between the two has occurred.

In such places and circumstances the result has too often been that sooner or later the weaker folk—those whose ancestors have been age long 'savages'—have died out in the presence of those whose ancestors long ago turned from 'savagery' to civilisation. This dying out of the weaker folk has happened even when the stronger people have done their best to avoid this extirpation.

The real ultimate cause of 'the decrease of natives' when in contact with civilised folk lies, perhaps, in the difference in hereditary mentality—in the incapacity of the 'savage' to take on civilisation quickly enough. However sedulously the missionary, the Government official, and others who take a real interest in so doing, may teach civilised precepts to the essential savage, the subject of this sedulous case—however advanced a savage culture he may have attained—will, at least for many generations, remain a savage, *i.e.*, for just so long as he is under influence of the civilised teacher he may act on the utterly strange precepts taught him, but away from that influence he will act on his own hereditary instincts.

The manner in which the native dies out—even when well looked after—varies. He may be killed out by some disease, perhaps trifling but new to him, with which he does not know how to cope, and with which—if he can avoid so doing—he simply will not cope in the ways which the civilised man would teach him; or he may be killed out by the well-meant but injudicious enforcement on him of some system of unaccustomed labour; or, again, he may die out because deprived of his former occupations (*e.g.*, fighting and the gathering of just so much food as sufficed for him) and thus restricted to a merely vegetative existence; or in many other more or less similar forms his extermination may come about.

But all such effective causes are reducible to one, which is that he is not allowed to act on his own hereditary instincts, that he cannot at all times have, and often would not use, judicious and disinterested guidance from civilised folk, and that consequently he, the 'savage,' cannot and too often does not care to keep alive when in the presence of civilised folk.

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *The Origin and Spread of certain Customs and Inventions.* *By* Professor G. ELLIOT SMITH, *M.A.*, *M.D.*, *F.R.S.*

After dealing with the evidence from the resemblances in the physical characteristics of widely separated populations—such, for instance, as certain of the

ancient inhabitants of Western Asia on the one hand and certain Polynesians on the other—suggesting far-reaching prehistoric migrations, the distribution of certain peculiarly distinctive practices, such as mummification and the building of megalithic monuments, is made use of to confirm the reality of such wanderings of peoples, the author said:—

'I have already (at the Portsmouth, Dundee, and Birmingham meetings) dealt with the problem as it affects the Mediterranean littoral and Western Europe. On the present occasion I propose to direct attention mainly to the question of the spread of culture from the centres of the ancient civilisations along the Southern Asiatic coast and from there out into the Pacific. From the examination of the evidence supplied by megalithic monuments and distinctive burial customs, studied in the light of the historical information relating to the influence exerted by Arabia and India in the Far East, one can argue by analogy as to the nature of migrations in the even more remote past to explain the distribution of the earliest peoples dwelling on the shores of the Pacific.

'Practices such as mummification and megalith-building present so many peculiar and distinctive features that no hypothesis of independent evolution can seriously be entertained in explanation of their geographical distribution. They must be regarded as evidence of the diffusion of information, and the migrations of bearers of it, from somewhere in the neighbourhood of the Eastern Mediterranean step by step out into Polynesia and even perhaps beyond the Pacific to the American littoral.'

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2. *The Short Cists of the North-East of Scotland.* *By* Alexander Low, *M.A.*, *M.D.*

The Short Cists of the North-East of Scotland are single interments found mostly without any overground structure to indicate their site. The cists are built of irregularly shaped flat stones set on edge, and roofed over by one large flat covering stone. The internal dimensions vary, but an average cist measures three feet long by two feet wide and one foot six inches deep. There is no evidence of the cists being oriented in any particular direction. In the cists examined burial was by inhumation. There is evidence to show that, while burial by inhumation was the earlier practice, inhumation and incineration were partly contemporaneous; and this is borne out by one cist, in which along with a burial by inhumation were found calcined human bones.

Besides the skeletal remains there were associated with the interments clay urns, flint scrapers, flint arrowheads, but no trace of metal. The urns were all of the 'beaker' type, except in one instance, where the urn was of the 'food-vessel' type.

We have made a detailed examination of a series of fifteen somewhat complete, short cist skeletons preserved in the Anatomy Department of the University of Aberdeen. The skull form is very uniform in its characters. A skull, from a short cist recovered at Parkhill, Aberdeenshire, may be taken as representative of the type. The skull is that of a male, sutures partly closed, frontal and parietal eminences well developed, cubic capacity 1,450 (of mustard seed), horizontal circumference 524, glabello-occipital length 135, minimum frontal diameter 102, interzygomatic breadth 142, nasio-alveolar length 64, nasal height 48, nasal width 23, orbital width 41, orbital height 33. With a length-breadth index of 85, the measurements are those of a brachycephalic skull with low broad face, microseme and almost mesorhine. The *norma lateralis* shows an orthognathous face with well-formed chin, depressed nasion, well-marked superciliary ridges, frontal arc ascending with a uniform steep curve to bregma, behind this there is flattening, and then the postero-parietal passes down sharply to the lambda and is associated with occipital flattening.

Altogether the series of skeletal remains gives evidence of a people of somewhat under medium stature, well-built and athletic, with very broad skulls, low straight faces, narrow orbits and somewhat broadish noses.

As to the affinities of these short cist builders, the characters of their skeletons are very similar to those of the broad-headed Alpine race that occupied Central Europe about the end of the Stone Age and which are supposed to be

descendants of the Palæolithic broad-headed Grenille race; in fact, the short cist skull approximates closely to the Grenille type of skull. The ceramic found in the interments supports this view, for the Hon. John Abercromby has demonstrated that the 'beaker' type of sepulchral urn is the oldest Bronze Age ceramic, and that it is an imported type having its centre of dispersion in Central Europe at the end of the Stone Age.

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3. *The Stone Implements of the Australian Aborigine: the Types and their Occurrence.* *By* A. S. Kenyon *and* D. J. Mahony.

(1) *Distribution.*—Implements are found all over the land surface; mainly at 'camps,' but fortuitously more or less everywhere. 'Camps'—which embrace kitchen-middens, over-mounds, myrniong-heaps, cave-shelters, &c.—are of several classes. The first and most important comprises those which may practically be termed permanent, near unfailing water and reliable food supply. Others are, in a varying degree, of a temporary nature. These differences are reflected in the implements found at them. Temporary occupation, with surroundings calling for little or no use of stone implements, produces 'camps' like those on the Coorong Ocean Beach, South Australia, where there is no local stone or timber, and the food supply is limited to the mollusc, *Donax* sp. There are there thousands of acres of camp exposed; masses of *Donax* shells without, on the whole surface, more than a dozen shapeless fragments of flint: nothing else to show man's presence. The stone remains to be found at camps range from such rudimentary, almost unrecognisable, implements to series embracing every class to the highest, varying with the district and its available supplies of stone and with the situation.

(2) *Period.*—The whole of the implements dealt with are of recent age, and were fashioned by the race still existing. They occur on the surface or nearly so in positions where rapid accumulation is still in progress. No separation into layers of varying degrees of workmanship has yet been observed, while a mixture of all types is found on top of formations whose age cannot exceed a few hundred years. Certainly some stone occurrences which may imply antiquity have been reported, but they are not dealt with here.

(3) *Material.*—The material used varies with requirements and accessibility, but for cutting implements it may be readily divided into two classes, brittle and hard stone, such as flints, quartzites, cherts, &c., and the tougher but softer diabasic, metamorphic, and like rocks. Barter is almost wholly confined to the latter class, and in it to the better sorts. The brittle stones produce implements of palæolithic, and lower, types; the tough stones mainly those of a neolithic character.

(4) *Type.*—There is no doubt that the class of stone available governs the degree of finish and method of manipulation, with use and opportunity playing a secondary part. At Portland, where flints abound along the coast line and no other suitable stones occur, the implements of flint, forming the great majority, are of a marked palæolithic type; most, if not all, of the types so classed in Europe being obtainable. Were these the only indications, it might be claimed that a race but little higher than the Tasmanian had existed on the mainland. On the Upper Goulburn River, where there are no flints and no quartzitic rocks of a tractable nature, a completely distinct group of implements is met with. The river pebbles, flattened ovals in form, are made implements by simply chipping around one edge. In the remote interior of the Mallee Scrub, where good brittle stone is obtainable only from great distances, each fragment is used and re-used until a complete series of minute implements of 'pygmy' type is found. Even with such crude and cumbersome implements as stone-mills, the same law holds. In proximity to suitable sandstone, large roughly broken masses of stone are used, while at a distance the smaller quarried types prevail.

(5) *Classification.*—The first requirement is one system capable of including all forms, from the most primitive eolithic to a well-differentiated and fashioned neolithic implement. No existing European or American system is applicable, as all postulate a relationship between the workmanship and the cultural stage of the artificer: this is not justified by Australian evidence. Consequently the

classification adopted is that of Kenyon and Stirling (Royal Society of Victoria, vol. xiii. n.s. 1901), with such modifications as later discoveries have rendered necessary. This system is founded primarily on use, though form has to be relied upon in instances where use is merely conjectural.

(6) *Conclusion.*—In Australia at least the type of implement prevailing is no reliable index to the type of man who fashioned it, or to his stage of culture, or to his period of existence. But for the undeniable evidence as to the contemporary nature of the various camps, the conclusion would be justified that they are the remains of former inhabitants of neolithic, palæolithic, and, to coin a term, protolithic ages.

TUESDAY, AUGUST 18.

The following Papers were read :—

1. *Some Extensions of Early Stone Age Culture.* *By* H. Balfour, *M.A.*

2. *Recent Excavation of a Palæolithic Cave in Jersey.* *By* R. R. Marett, *M.A., D.Sc.*

During the past three years fruitful exploration of the cave known as La Cotte de St. Brelade, on the south coast of Jersey, has taken place, and the results were laid by me before the British Association at the Portsmouth, Dundee, and Birmingham Meetings. This year for the first time the British Association has taken an active share in the work by making a grant of 50*l.*, and appointing a Committee of control. This latest chapter in the history of the excavation may fairly claim to have broken all previous records.

Hitherto the Mousterian floor had been cleared only along the west side of the cave, where about twenty-five feet of superincumbent débris had to be removed. It was now resolved to carry the clearing across the mouth to the east side, though this involved the demolition of an overlying mass of no less than forty feet, weighing approximately a ton to every square foot of floor exposed. Considerable risk from falling stones had to be faced, but only one accident occurred, and that fortunately not very serious.

As the east limit was approached, the floor of ancient occupation increased in thickness; so that near the wall, which was found to be undercut by a considerable cavity forming a sort of side-chamber, as much as twelve feet of hearth-deposits, rich in bones and implements, were encountered.

Among the bones a rough preliminary survey reveals the presence of mammoth, woolly rhinoceros, the great Irish elk, reindeer, red deer, roe deer, wild ox, wild horse, wild goat, cave-hyæna, fox, arctic lemming, and a species of grouse. We have here, then, a thoroughly representative pleistocene fauna of the cold, or tundra, type.

The number of implements obtained may be gathered from the fact that they exceeded three cwt. in sheer weight. It will take months of study to do justice to the wealth of types which they embody. As far as can be made out at present, the Mousterian facies prevails throughout, though it remains to be seen whether it will prove possible to differentiate in regard to style of workmanship the products of the various levels of the floor. In the meantime it may be pointed out that the characteristic 'point' was found at all levels; though one of these, gathered at the lowest level, was worked on both sides, thus suggesting the technique of an earlier period. Among the smaller implements a certain number appeared to be notched towards the base, as if they had once been provided with a handle or shaft. There was a great variety of hammer-stones, mostly of granite, and of split pebbles, mostly of diabase, some of which had clearly been used as polishers. Altogether, this site is so rich that it may well come to be treated as the *locus classicus* for the determination of the leading forms of the Mousterian culture; more especially as, to judge from the thickness of the implementiferous bed, and the occurrence of double patination upon

certain implements, the occupation must have extended over an immense period of time.

There is still a great deal of work to be done on this site, and, what is more, it promises to be immediately fruitful on both sides of the recent cutting. It is to be hoped that the British Association will not hesitate to provide a fresh grant, and thus identify itself still further with discoveries that cannot fail to make for the advancement of archæological science.

3. *The Brain of Primitive Man. By* Professor G. Elliot Smith, *F.R.S.*

4. *On the Relations of the Inner Surface of the Cranial Wall to the Brain, with special reference to the Reconstruction of the Brain from Cranial Casts. By* Professor J. Symington, *M.D., F.R.S.*

This paper contained the results of a series of observations on the relations of the brain and skull with the object of ascertaining the extent to which casts of the cranial cavity enable us to estimate the form of the brain and especially the position of the cerebral fissures and the degree of development of the cerebral convolutions. As is well known to anatomists, the bony wall of the cranium is separated from the brain by three membranes called the dura mater, the arachnoid, and the pia mater. As a rule these membranes are thin, but in certain situations they may be thickened, or separated from one another; thus, meningeal vessels ramify on the outer surface of the dura mater, and certain venous channels, some of considerable size, are situated in the dura mater, while between the arachnoid and the pia mater is the cerebrospinal fluid, and the larger cerebral vessels lie in the subarachnoid space and the smaller ones in the pia mater.

In a series of specimens in which the brain had been carefully hardened *in situ* the cranial cavity was opened and the brain divided in a horizontal, transverse vertical, or median direction. Plaster of Paris or gelatine casts were taken of part of the cranial cavity, first with the dura mater *in situ* and secondly after removal of this membrane. Moulds were also made of the part of the brain which occupied the portion of the cranial cavity from which casts had been taken. These moulds of the brain were made with the arachnoid and pia mater in position and also after their removal; and from them casts were prepared. One complete set of such casts consisted of (1) the inner surface of the bony wall of the skull, (2) the inner surface of the dura mater, (3) the outer surface of the arachnoid, and (4) the outer surface of the brain.

In thirteen adult subjects the vault of the skull and its contents, and in two the parts behind the foramen magnum, were examined, and in three the head was divided in the median plane and the lateral halves cast. With the aid of this material not only could the form of the brain and of the cranial cavity be compared, but the structures to which were due any differences between them could easily be demonstrated.

The results of this investigation showed that only the general form and size of the brain and the position of but few of its fissures and convolutions could be ascertained from the bony cranial casts, and that the simplicity or complexity of the cerebral convolutions could not be inferred from the feeble or marked development of the digital impressions on the inner surface of the cranial wall. These observations tend to throw grave doubts on the reliability of certain statements with reference to the peculiarities of the Piltdown brain based upon casts of the Piltdown cranium.

5. *Bori Exorcism, Fortune-telling, and Invocation. By* Major A. J. N. Tremearne, *M.A., LL.M.*

A woman in Tunis had been ill for seven months, her body so lax that she could do nothing. After four and a half months she had given one franc, to be wrapped in a handkerchief and hung in the bori temple as an offering to Kuri. She got a little better, and at the end of the seventh month gave a dance. Her

illness was transferred to two fowls, which were then killed, and various bori came and entered the dancers. The patient was so much benefited that she was able to dance herself by midnight, and was walking about next day.

The *godiya* ('mare') having become affected by the inhalation of incense gave oracles and answered the questions asked. Several spirits mounted. During the inhalation the priestesses rubbed the ground, and during the possession of the *godiya* they knelt and received *albaraka*. An incantation was sung to each spirit on arrival by a special songstress.

When a person is going on a journey, fowls may be sacrificed after an invocation to the bori, and the blood flowing between the traveller's legs brings the bori, who give their *albaraka*. By the manner in which the blood flows and by its appearance the success of the venture may be foretold.

6. *Culture and Degeneration.* *By* Professor F. von Luschan.

WEDNESDAY, AUGUST 19.

The following Papers were read :—

1. *Is Australian Culture Simple or Complex?*
By Dr. W. H. R. Rivers, *F.R.S.*

The question whether Australian culture is simple or complex is one of great theoretical importance. If this culture does not represent a stage in, or an offshoot from, a direct line of social development, but is the result of the fusion of a number of elements which reached Australia at long intervals, the first step towards any sound knowledge must be the analysis of this culture. If such features of Australian culture as its totemism, its belief in the reincarnation of the dead, and its practices of mutilation are not independent developments, but the results of influences brought to Australia from elsewhere, perhaps in relatively recent times and by people whose culture was of a higher order than that now found in Australia, the foundation on which many recent anthropological speculations have been reared is swept away.

In considering this question, the first point to be noted is that it is impossible to decide whether any culture is simple or complex by a study of that culture alone. It is only by comparison with neighbouring and allied cultures that the problem can be settled. The first question, therefore, which must be asked is whether any culture allied to that of Australia exists in its neighbourhood, and there can be no question that Melanesia possesses such a culture. Superficially the two are very different, but the more one studies those aspects of culture which do not lie on the surface, such as social structure and religion, the more apparent does the close relation between the two become. The complexity of Melanesian culture is evident, and the results of an attempt [1] to analyse this complexity leave little doubt that some of the elements which resemble those of Australia most closely have been brought from elsewhere or have arisen out of the interaction between the indigenous and immigrant peoples.

Further, it is almost, if not quite, certain that the cultures which have reached Melanesia from without have come from the west, the immediate centre of dispersion having been the Malay Archipelago, and it is evident that the same influences have reached the remotest parts of Polynesia, as well as Madagascar. It seems hardly possible that migrant peoples setting out from the Malay Archipelago and reaching such remote islands as Hawaii, Easter Island, New Zealand, New Caledonia, and Madagascar, can have failed to reach and influence a vast continent which lies quite near their home. It is probable that the main path of movements eastward from Malaysia lies north of New Guinea, and Australia might thus have escaped, but even if it be conceded that all the movements so passed, and this is most unlikely, the

[1] Rivers, *History of Melanesian Society*, Cambridge, 1914.

advocates of unity would be in no better case, for it is certain that the migrants turned the south-eastern corner of New Guinea and passed westwards. Culture-movements which passed in this direction as far as the Fly River of New Guinea are not likely to have escaped Australia.

It is a most important point that these migrants must have been seafarers and would have reached Australia by sea. Seafarers so enterprising that they reached Easter Island and Madagascar are not likely to have been content to invade Australia at one point; they would have coasted far in search of favourable settling-places. One reason why so many students have been blind to the possibility of external influence in Australia is that they have pictured the process as the sweeping of an invading host across the continent. The history of Australian culture and its present nature become far easier to understand if there has been a gradual infiltration of seafaring peoples, starting from many points on the coast; if immigrants, few in number, first formed small settlements on the coast and passed on their culture to the interior of the continent by gradual secondary movements.[2]

One difficulty which confronts this view is the apparently primitive character of the seafaring vessels of Australia. The view I put forward can only stand if there has taken place in this region that degeneration and even loss of so useful an object as the canoe of which we have definite evidence in Melanesia and Polynesia.[3]

The complexity of Australian culture will only be established when the facts of Melanesian, Papuan, and Australian culture have been fitted into a common scheme, and I may consider here one feature of culture to illustrate the kind of process by which this object may be attained. The analysis of Melanesian culture has shown[4] that certain main varieties of the modes of treating the bodies of the dead can be ascribed to immigrant peoples. This ascription rests partly on the distribution of these modes of disposal; partly on the association of these modes with other elements of culture; partly on the use of different modes by chiefs and commoners. The chief modes of disposal of the dead which occur in Melanesia are also found in Australia. In order to prove that the two sets of customs have had a common origin, it will be necessary to show that the Australian modes of treating the dead are associated with those elements of culture with which they occur in Melanesia.

The object of this introduction is to state a problem and to put forward certain facts and principles which must be taken into account in attempting its solution. The history of Australian culture can only be learnt by a study of the distribution of its elements of culture in which far more attention is paid to the details of social structure and religious practice than has hitherto been given by advocates of Australian complexity.

SYDNEY.

FRIDAY, AUGUST 21.

After the President had delivered his Address (see p. 515) the following Papers were read :—

1. *The Roman Advance into South Italy.* *By* THOMAS ASHBY, *D.Litt.*

One of the greatest factors in the Roman conquest of Italy and of the Roman world was the excellence of the system of military roads which she constructed. The earliest beginnings of this system may be traced in the immediate neighbourhood of Rome itself, from which roads radiated in all directions. As the Roman power increased the military highways were pushed forward, each important

[2] See *Essays and Studies presented to William Ridgeway*, Cambridge, 1913, p. 479.

[3] *Festskrift t. Edvard Westermarck*, Helsingfors, 1912, p. 109.

[4] *History of Melanesian Society.*

advance into hostile country being secured by the plantation of a Roman or Latin colony (*i.e.*, the construction of a fortress, peopled by soldiers) and united by a road to the base. The study of the Roman road system is thus very important from an historical and a military point of view. An account was given in 1913 at the Birmingham Meeting of researches along the Via Appia and the Via Traiana, and in continuance of it the remainder of the road system of South Italy is now described, as the result of actual exploration on the spot, the line of the ancient roads being traced and followed as far as possible—an enterprise not always by any means easy.

2. *Preliminary Communication on an Australian Cranium of probable Pleistocene Age. By* Professors T. W. Edgeworth David, *C.M.G., F.R.S., and* J. T. Wilson, *F.R.S.*

Professor T. W. Edgeworth David stated that the skull exhibited belonged to Mr. E. C. Crawford, of Greenthorpe, New South Wales, who obtained it from a stockman, who found it in the bed of Talgai Creek, near Clifton, on the Darling Downs of Queensland. It appears to have been washed out of the black soils of the Darling Downs. A few miles from the spot where the skull was picked up bones of many types of extinct mammalia of Pleistocene Age have been discovered, and as the present skull is in at least as advanced a stage of fossilisation as the bones of *Diprotodon, Nototherium*, etc., in adjacent regions, it may provisionally be assumed that this human skull is also of Pleistocene Age. The distortion caused by steady pressure due to the weight of an original thick overburden of clay is in harmony with the evidence as to the high antiquity of the skull.

While there is a strong probability of this fossil skull being of Pleistocene Age, perhaps early Pleistocene, its exact age obviously cannot be determined until further evidence can be adduced which may directly connect it with the mammalian bone-bearing clays of the Darling Downs. Certainly it is far older than any aboriginal skulls that have ever been obtained in Australasia, and it proves that in Australia man attained to geological antiquity.

TUESDAY, AUGUST 25.

Discussion on the Study of Native Culture in relation to Administration, opened by Dr. A. C. Haddon, *F.R.S.*

The following Papers were then read:—

1. *Gerontocracy and Marriage in Australia. By* Dr. W. H. R. Rivers, *F.R.S.*

Certain peculiar forms of marriage which occur in Melanesia, such as marriage with the granddaughter of the brother, with the wife of the mother's brother, and with the wife of the father's father, are capable of explanation as the result of a state of dominance of the old men, which allowed them to monopolise all the young women of the community.[1] Since Australia furnishes an example of a gerontocracy in which the old men are known to monopolise the young women, we should expect to find these peculiar marriages in Australia. Until now, however, only one has been recorded, the Dieri marrying the granddaughter of the brother,[2] but Baldwin Spencer has recently recorded others in the Northern Territory.[3] Wives are transferred to the sisters' sons (as well as to the sons) in the Kakadu tribe, while nearly all the systems of relationship collected in the Northern Territory show the presence of marriage with the wife of the father's father, sometimes combined, as in Melanesia, with

[1] Rivers, *History of Melanesian Society*, Cambridge, 1914.
[2] Howitt, *Native Tribes of South-East Australia*, pp. 164, 177.
[3] *Native Tribes of the Northern Territory of Australia*, 1914.

the cross-cousin marriage. All the forms of marriage which would be the natural result of monopoly of the young women by the old men are thus now known to accompany the gerontocracy of Australia.

2. *Varieties of Totemism in Australia.* *By* A. R. BROWN.

For the purposes of this paper totemism is defined as a special magico religious relation between an individual or a social group, on the one hand, and a class of natural objects, generally a species of animal or plant, on the other.

Considering first of all the nature of the totemic group we can distinguish the following different kinds of totemism in Australia:

(1) *Clan totemism with female descent.* The totemic group is a body of relatives who form a clan. Every child belongs to the same totemic group as his mother. This form of totemism is found in many tribes in the eastern part of Australia, such as the Kamilaroi.

(2) *Clan totemism with male descent.* The totemic group is a body of relatives. A child belongs to the same group as his father. This form of totemism seems to exist in widely scattered regions of Australia; for example, in the Kariera tribe of Western Australia, in some of the tribes of the Northern Territory, in the Narinyeri tribe of South Australia, and perhaps in some tribes of Victoria and the southern part of New South Wales.

(3) *Local group totemism.* The totemic group is a body of persons living in the same place and collectively owning and occupying a definite portion of the tribal territory. The group is not a clan and is not exogamous. A child belongs to the same local and totemic group as his father. This form of totemism is found in the Burduna tribe of Western Australia, and in a number of neighbouring tribes.

(4) *Cult society totemism.* The totemic group is a body of persons who are all qualified to take part in a certain cult. The best known example of such totemism is that found in the Aranda tribe of Central Australia.

(5) *Totemism of the dual division.* The tribe is divided into two parts or moieties, and each part is associated with some species of natural object, as eaglehawk and crow in some tribes.

(6) *Totemism of relationship divisions.* The totemic groups are the four sections or the eight sub-sections into which the tribe is divided by the system of relationship. One variety of this form of totemism is found in the Pita-pita and other tribes of Western Queensland. Another variety is found in the Mungarai and Punaba and other tribes of the Northern Territory and Western Australia. A third variety is found in the tribes at the head of the Gascoyne and Ashburton Rivers in Western Australia.

(7) *Sex totemism.* The tribe is divided into two parts, males and females, all the males having a special relation to one species of bird or plant, while all the females have a similar relation to a different species.

(8) *Personal totemism.* The individual has a special and purely personal relation to some one or more species of natural objects. In the best-known form, that of the Yualai tribe of New South Wales, only medicine-men and women with special magical powers have personal totems.

Considering now the nature of the relation between the group or the person and its or his totem, we may distinguish three main kinds of totemism according as we find (1) a definite positive ritual associated with the totem, (2) a negative ritual, or (3) no organised ritual at all.

Two main types of positive ritual have so far been described. One of these I propose to speak of as the Talu cult, from the name of the ceremonies in a number of tribes of Western Australia. Each totem has a special spot sacred to it, which we may call the 'totem centre.' At this spot members of the totemic group perform ceremonies that are believed to result in an increase in the numbers of the totemic species. A totemic cult of this type is found over a large part of Western Australia, over a part of the Northern Territory, and in South Australia in the Arabana and Dieri tribes. It is found associated with clan totemism with male descent, with local group totemism, and with cult society totemism.

Another type of totemic cult I propose to speak of by the name Thuthu, by

which it is known in the Waramunga tribe. The ceremonies of this cult are not localised, but may be performed anywhere. Each ceremony consists of a representation of the totemic ancestors of the group and of some of their actions. This cult has so far only been recorded from the Northern Territory and South Australia. It exists side by side with the Talu cult in the Aranda tribe, and also in the Waramunga tribe, where, it would seem, the Talu cult is unknown.

There are hints of the former existence of a cult perhaps similar to the Thuthu cult in some of the tribes of New South Wales, as, for instance, the Yualai.

As regards negative ritual this usually takes the form of a prohibition against killing or eating the totem. In the Aranda tribe a man may not eat his own totem, *i.e.* the totem of the cult society to which he belongs, except on certain ritual occasions. In Western Australia, in the tribes with clan totemism and local group totemism (Kariera and Burduna) a man may freely kill and eat his own totem. In the tribes of the east of Australia with totemic clans, with female descent the general rule would seem to be that a man may eat his own totem, but he must respect it. For instance, he would only eat it if there were nothing else and he was hungry, and he would express sorrow at having to eat it.

In Western Queensland a member of a relationship section may not eat any of the animals that are the totems of his section, though he may eat those belonging to the section of his father or his mother or his wife. In the Yualai tribe a man may not eat his own personal totem.

In the case of sex totemism there is a sort of reversed negative ritual. A woman may not kill the totem of the men, or the men will be angry, and *vice versa*.

In the case of the totems of the dual division it would seem that in general there is no ritual, positive or negative.

Taking these distinctions as the basis of a classification we may consider briefly a few of the types of totemic organisation about which we have most information.

Kariera Type.—Totemic clans with male descent. Each clan has a number of totems (multiple totems). Cult of the Talu type. No prohibition against killing or eating the totem.

Burduna Type.—Local group totemism. Each local group has one or more totems. Cult of the Talu type. No prohibition against killing and eating the totem. The local groups are united into inter-tribal totemic divisions, all groups having the same totem being included in the same division.

Punaba or Mungarai Type.—Each of the eight sub-sections into which the tribe is divided has one or more totems.

Anula Type.—Totemic clans with male descent. Totemic cult of the Talu type. A man may not eat his own totem, and may only eat sparingly of his mother's totem.

Waramunga Type.—Totemic clans with male descent. Thuthu cult, but no Talu cult. A man may not eat his own totem.

Aranda Type.—Totemism of cult societies, membership of the totemic group being determined by the locality near which the individual was conceived by his mother. Cult of the Talu type. A man may not eat his totem.

Pita-pita Type.—Each of the four sections of the tribe has a number of totems. No positive cult recorded. A man may not eat his own totem.

Yualai Type.—Clan totemism with female descent. Each clan has one chief totem and a number of subsidiary totems. Probably there is a cult of the Thuthu type. A person may eat his clan totem. Personal totems of men and women with magical powers. A person may not eat his personal totem.

Dieri Type.—Clan totemism with female descent. No cult of these totems (*madu*) recorded. Also clan totemism with male descent, in connection with which there are ceremonies of the Talu type.

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3. *Some Nature Myths from Samoa.* *By* Rev. George Brown, *D.D.*

As regards the manner in which these myths were collected, it was stated that they were written about fifty years ago by a Samoan poet, in his own handwriting and without any communication with white men.

The myths selected were those dealing with the war between birds and fishes. These were supplemented by the native account of the Palolo (*Palolo viridis*), showing the way in which the Samoans calculate the time when that annelid appears. The paper was intended to show the development of the mind of men, in primitive conditions of life, from 'animatism' to 'animism,' and onwards again to 'natural science,' after many years of close observation of natural phenomena.

4. *The Ancient Inhabitants of Egypt and the Sudan.* By Professor G. Elliot Smith, *M.A., M.D., F.R.S.*

This communication dealt with new material bearing upon the racial characteristics of two groups of the earliest people, the most northern and the most southern, whose remains have yet come to light in the Nile Valley: (*a*) one a series of Protodynastic skeletons obtained from various sources within forty miles of Cairo, and (*b*) another set recovered by Dr. Reisner near Merowe, many hundreds of miles further south, in the Sudan.

(*a*) The evidence of the first series supplements the information which the author has laid before the Association from time to time during recent years, and seems to indicate that the alien element in the Protodynastic population of Lower Egypt can be recognised as early as the time of the First Dynasty. It raises the possibility that from an even more remote period the people of the Delta may have been intermingling with a foreign population not belonging to the Brown Race. Moreover, the general diffusion of alien traits in the people of Memphis by the time of the Second Dynasty and the complete gradation of types intermediate between the typical Proto-Egyptian of Upper Egypt and the Syrian of Western Asia suggests a long process of intermingling of these two peoples in Lower Egypt before that time.

(*b*) The interesting material from the Sudan was obtained last year by Dr. Reisner at the southern end of the Kerma basin. It belongs to the Hyksos period, when large numbers of Egyptians emigrated into the Sudan. The skeletons obtained from the better tombs closely resemble those of typical Egyptians of the upper class, such as commonly occur in Upper Egypt from about the time of the VIth Dynasty onwards. But many of the other skeletons conform to the Proto-Egyptian and Middle Nubian (C group) types. Although none of the skeletons exhibit pronounced negroid traits, the majority of them bear indubitable evidence of some negro admixture, though in all cases it has affected the Egyptian or Nubian features only to a very slight degree.

5. *A Plea for Systematic Ethnological Research in Australia.* By W. D. Campbell.

6. *A Fundamental Problem of Religious Sociology.* By B. Malinowski, *Ph.D.*

There are certain questions of principle in every branch of science which cannot be passed over in any comprehensive and thorough treatment of the subject, and upon the answer of which the further course of inquiry essentially depends.

Such questions are, as a rule, the most difficult to settle, because only an overwhelming amount of evidence gathered with the very problem in view allows of an unequivocal answer. In anthropology the mutual co-operation of the theorist and of the field-worker is essential in all such cases.

A question of this type presents itself at the outset in anthropological investigations of religion. Is there a sharp and deep cleavage between *religious* and *profane* matters among primitive peoples? Or, in other words: Is there a pronounced dualism in the social and mental life of the savage, or, on the contrary, do the religious and non-religious ideas and activities pass and shade into each other in a continuous manner?

This question is of utmost importance for the general theory of religion.

Professor Durkheim postulates the existence of a perfectly sharp and deep cleavage between the two domains of the *sacré* and profane, and his entire theoretical construction stands and falls with this assumption.[1] Again, Dr. Marett is of opinion that, generally speaking, 'the savage is very far from having any fairly definite system of ideas of a magico-religious kind, with a somewhat specialised department of conduct corresponding thereto.'[2]

This view, although expressed in a somewhat different connection, undoubtedly implies the negation of Durkheim's dogmatic standpoint. Again, Mr. Crawley thinks, that for the savage everything has got a religious dimension,[3] a view which also excludes the existence of any irreducible dualism of *magico-religious* on the one hand and *secular* on the other.

These examples show that the above question, fundamental as it is, is still unsettled and controversial. What answer does it receive from the ethnographic evidence? The great Australian ethnographers, Spencer and Gillen, whose researches have contributed to the advancement of our knowledge of primitive religion more than any other investigations, answer the question in the affirmative. The life of an aborigine of Central Australia is sharply divided into two periods: the one comprising his everyday life, and the other his magico-religious activities.[4] It is evident throughout Messrs. Spencer and Gillen's two volumes that the properly religious and magical practices and beliefs are strictly esoteric; that they are fenced off from everyday life by a wall of taboos, rules, and observances. Yet reading another standard work of modern anthropology, Dr. and Mrs. Seligman's monograph on the Veddas, one gets the impression that among these natives there does not exist anything like a radical bipartition of things and ideas into religious and profane.

Again, the views held by another recent investigator, Dr. Thurnwald, with regard to the magic of the natives of the Bismarck Archipelago and of the Solomon Islands, imply beyond doubt the absence of a clear-cut division between magico-religious and secular ideas,[5] the two classes merging into and blending with each other.

One conclusion seems to be inevitable: namely, that pending new evidence it would be rash to dogmatise on the subject under consideration. I venture to say more. The above-mentioned statements (which could easily be multiplied) point not merely to different personal equations, which, however, would be possible in such an enormously complex and general problem, but they point to real differences in the matter discussed. The consolidation of the religious life can be different amongst various peoples, depending as it does upon various social conditions. Thus religion seems to be best developed and possessing the highest relative social importance among the Central Australians, to a smaller degree among the Papuans studied by Thurnwald, still less among the Veddas. Where it is strongest the bipartition postulated by Durkheim seems to be most prominent. Wherever it is less pronounced the two domains shade into each other and begin to fuse.

Thus probably the division into *religious* and *profane* is not an essential and fundamental feature of religion, suitable to be considered as its very distinctive characteristic. It is an accidental feature, dependent chiefly upon the social part played by religion and connected possibly with some other factors, to determine the influence of which it is, however, necessary to have more ample evidence, gathered with the problem in view.

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7. *The Distribution of the Cylindro-conical Stones of Western New South Wales. By* R. Etheridge.

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[1] *Les formes élémentaires de la vie réligieuse*, Paris, 1912.

[2] *Notes and Queries on Anthropology*, 4th edition, London, 1912. Article on Religion.

[3] Article on Religion in *Sociological Papers*, iii., London, 1910.

[4] *Northern Tribes of Central Australia*, p. 33.

[5] 'Ethno-psychologische Studien an Südseevölkern,' in *Beihefte zur Zeitschrift für angew. Psychologie*, Leipzig, 1913. Paragraph on Magic.

8. *The Ethnological Collections of the Australian Museum, with Special Reference to the Bismarck Archipelago and New Guinea.* *By* R. ETHERIDGE.

9. *Craniological Observations on a Series of Solomon Island Skulls.* *By* S. A. SMITH.

10. *Observations on the Australian Aboriginal Humerus.* *By* S. A. SMITH.

11. *Notes on New South Wales Aboriginal Arborglyphs.* *By* E. MILNE.

12. *On Symmetrical Exostoses in the Acoustic Meatus in the Australian Aboriginal Skull, together with Demonstration of other Skeletal Characters.* *By* Professor J. T. WILSON, *F.R.S.*

13. *Polynesian Fish-hooks.* *By* C. HEDLEY.

14. *Australian Aboriginal Brains (with Exhibits).* *By* J. F. FLASHMAN.

15. *Exhibition of (a) Facsimile Coloured Drawings from Rock Shelters of South African Bushmen; (b) Illustration of Three Varieties of Rock Carving; (c) Reproduction in Natural Size of some Australian Aboriginal Paintings; (d) Photographs of South African Bushmen, their Occupations and Modes of Life.* *By* J. L. ELMORE.

16. *Exhibition of Teeth of the Dingo from the Breccia of the Wellington Caves, New South Wales.* *By* R. ETHERIDGE.

17. *Exhibition of (a) Australian Aboriginal Stone Tomahawk found at a depth of Ten Feet of Alluvium; (b) Drawings by an Aboriginal named 'Micky,' done in 1875.* *By* W. G. ENRIGHT.

SECTION I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION.—Professor BENJAMIN MOORE, M.A., D.Sc., F.R.S.

MELBOURNE.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

The Value of Research in the Development of National Health.

THE history of medical science presents to the curious student a remarkable development commencing in the latter half of the nineteenth century, and one worthy of special study, both on account of the light that it sheds on the present position and the illumination it affords for future progress.

If any text-book of medicine or treatise on any branch of medical science written before 1850 be taken up at random its pages will reveal that it differs but little from one written a full century earlier. If such a volume be compared with one written thirty-five years later, it will be found that the whole outlook and aspect of medicine have changed within a generation.

Erroneous introspective dreams as to the nature of diseases, as 'idiopathic' as the many strange maladies which their authors are so fond of describing have been replaced by fast-proven facts, and medicine has passed from an occult craft into an exact science based upon experimental inquiry and logical deduction from observation.

What caused this rapid spring of growth, after the long latent period of centuries, and are we now reaching the end of the new era in medicine, or do fresh discoveries still await the patient experimentalist with a trained imagination who knows both how to dream and how to test his dreams?

It is but a crude comparison that represents the earlier age as one of empiricism and imagination, and the later period as one of induction and experiment. Empiricism has always been of high value in science, it will ever remain so, and some of the richest discoveries in science have arisen empirically.

Imagination also is as essential to the highest scientific work to-day as it was a century ago, and throughout all time the work of the genius is characterised in all spheres of human endeavour by the breadth and flight of the imagination which it shows. The great scientist, whether he be a mathematician, a physicist, a chemist, or a physiologist, requires imagination to pierce forward into the unknown, just as truly as does the great poet or artist. Also, the inspired work of poet or painter must be concordant with a system of facts or conventions, and not outrage certain canons of his art, as certainly as the true and lasting work of the scientist must accurately accord with natural laws.

The scientist is as little able to prove the fundamental truth or existence of the groundwork upon which modern physical, chemical, and physiological theories are built, as the artist is to prove the ethics, or perfect truth, or perfect beauty, of those conventions upon which poetry, painting, or that great group of studies termed the 'humanities' find their basis. But the artist or philosopher knows that, using these conventions as the best at present discovered,

he can produce works of which the beauty and consistency appeal to all educated human minds capable of appreciation. Similarly, the conventions of natural science, properly understood, appeal to the imagination of the scientist, call forth new ideas to his mind, and suggest fresh experiments to test those ideas; or, a chance empirical observation of an experimental nature, which without theory and scientific imagination would remain isolated and sterile, placed in relationship to the rest of the scheme of science, awakens thought, and may lead to a fresh departure and a long train of important discoveries.

It was this correlation of the imagination with experimentation and the tracing out of relationship from point to point so as to develop the evolution of phenomena that characterised the science of medicine when new-born about seventy years ago, and differentiated it from the older nosological medicine in which imagination and experimentation, while both existing, seemed to possess independent existences and pay little regard the one to the other.

It seems well-nigh forgotten nowadays by the majority of people that science and religion originally began together from a common thirst for knowledge, and usually in the same type of mind endowed with a divine curiosity to know more of the origin and nature of things.

Every great religion worthy of the name contains some account of the natural history and creation of the world, in addition to its metaphysical aspects, and reflects the degree of knowledge of natural science possessed by the nation in which it arose at the time of its birth.

The fundamental error throughout the ages of human conceptions both in science and religion was that of a non-progressive world to which a stereotyped religion, or science, could be adapted for all time. Perfection was imaged where perfection, we are now happy to realise, was impossible, and, believing in this imaginary perfection and that all things new deviating from it were damnable, men were prepared to burn one another at the stake rather than allow error to creep into the world in either science or religion. Thus there have been martyrs for the scientific conscience just as for religious belief, and at this distance in time we can perhaps better understand both inquisitor and martyr and realise that both were fighting for great ideals.

Evolution has taught us that as knowledge broadens we must be prepared to have wider vision and abandon old theories and beliefs in the new-born light that makes the world better to-day than it was yesterday, and that also will show things up to our mental vision more clearly to-morrow than they stand out to-day. To the members of any great craft, or profession, or religious order, this scientific outlook, which accepts as fundamental a progressive world and insists that its votaries should adapt their lives to such a doctrine, is peculiarly difficult of assimilation. Routine fixes all men, and so when any new discovery appears to demand change from that order to which the mind has become accustomed, it is immediately looked upon with suspicion, and there being little plasticity of mind remaining, it is rejected as heretical or revolutionary after but scanty critical examination. The cry of the craft in danger has been used efficaciously on many occasions since the days of the Ephesian silversmiths, nor is such a cry at once to be set down to pure selfishness. A craft is often worth preserving long after the forces which have called it into being have commenced to slumber, and conservatism of this type is at times an important factor in social progress. However, there are certain limits which must not be surpassed, room must be made by adaptation for the new knowledge, or it will establish a craft of its own iconoclastic to much worth preserving in the older system.

It is important to insist upon these limitations, because a too reactionary spirit abroad in medicine between 1860 and 1880 prevented the world from benefiting from those remarkable discoveries by Pasteur and their proposed applications by Lister, which laid the foundations of modern medicine and modern surgery. These pioneers of the new age in medical science had to wage for many years a stern and bitter fight against the strong forces of ignorance and prejudice. But for this illogical resistance by men who would not even test the new discoveries, and instead spent their time in sneering at the new geniuses who had leadership to give the world, France and Germany would have been saved many thousands of brave lives in the great war of 1870-71,

Even thereafter, the slow struggle continued of the few who knew against the many who refused to be taught, and a perusal of any orthodox text-book of medicine published between 1875-80—that is, more than a decade after Pasteur's great discovery—will show that the etiology of scarcely a single infectious disease had become known, and that medical science was, for example, as ignorant of the nature of tuberculosis as we are to-day of the nature of carcinoma. Take, as an example, the following quotation from a well-known text-book of the theory and practice of medicine published in 1876: 'It is now, however, generally admitted that tubercle is no mere deposit, but, on the contrary, a living growth as much as sarcoma and carcinoma are living growths.' The tubercles were the only initial lesion observed, the infecting organism was entirely unknown, and the pathologists of this comparatively recent date argued at length as to whether tubercles were to be classed as 'adenomata' or were something *sui generis*.

There is a gleam of sunlight for the future in this retrospect at the ignorance of the past, for, if men were as ignorant regarding tuberculosis thirty-eight years ago as to-day they are about cancer, then it may be argued that a generation hence as much may be known about cancer as is known now about tuberculosis.

It is particularly important at the present moment, when so much interest is being taken in national health, to point out the urgent necessity of allowing as little lagging behind as possible to ensue between the making of discoveries and the practical application of the results by organised national effort for the well-being of the whole community.

It must sadly be admitted that it is craftsmanship in imaginary danger fighting hard for the old methods unchanged which were in vogue fifty years ago, that stands most prominently in the way of advance. As great a harvest as that which followed the application of the principle of antisepsis in surgery awaits the application of the self-same principle in national sanitation to-day, but the very profession which ought to be urging forward the new era apparently stands in dread of it, and seems to prefer to reap its harvest from disease rather than to seize the noble heritage won for it by the research of pioneers and so stand forth to the world as the ministry of health. Fortunately it cannot be, the bourne has been passed, and there is no going backward. The advances that have already been made have awakened statesmen and people alike to the needs of the situation, and all have resolved to be disease-ridden no longer. The laws of health must be made known to the people at large, and schemes laid before them for a national organisation for the elimination of disease. Disease is no longer an affair of the medical profession, it is a national concern of vital importance. The problem is not a class question, all humanity stands face to face with it now in the light of modern research as it never has faced it before. It has been realised that disease never can be conquered by private bargains for fees between individual patient and individual doctor. Research into diseases of unknown causation cannot be subsidised upon such individualistic lines, and in the case of diseases of known etiology and modes of propagation the passage of disease from individual to individual cannot be controlled by such private methods as that of the afflicted individual subsidising the doctor for his own protection. Cost what it may, a healthy environment must be produced for the whole mass of the population, and the laws of physiology and hygiene must be taught not only to medical students, but to every child in every school in the country. People cannot live healthy lives in ignorance of the fundamental laws of health merely by paying casual visits to physicians, and no one class in the community can be healthy until all classes are healthy.

The problem of national health is one of peculiar interest to physiologists, and to the exponents of those experimental branches of medical science which have sprung from the loins of physiology, for it was with them that the new science of medicine of the last fifty years arose, and they ought to be the leaders of the world in this most important of all mundane problems.

It is well worth while to consider our opportunities and responsibilities and raise the question whether our present system and organisation are the most suitable for attaining one of the most sublime ambitions that ever appealed to

any profession. By definition, our science studies the laws of health and the functions of the healthy body, therefore it is ours to lead in the quest for health. Is this object best achieved if we confine ourselves to research in our laboratories, and to the teaching of the principles of physiology to medical students, while we leave the community as a whole uninstructed as to the objects of our research and its value to every man, and trust the medical students whom we turn out to communicate, or not communicate as they choose, the results of their training and our research to the world at large?

There is little question that much of the ignorance abroad in the world, and much of the fatuous opposition to our experimental work and research, arise from this aloofness of ours. Here also lies the cause of much of the latent period in the application of acquired knowledge to great sociological problems, and the presence of untold sickness and death which could be easily prevented if only a scientific system of dealing with disease could be evolved.

The position occupied by scientists in medicine at the present day is largely that of schoolmasters to a medical guild, and even at that, one constructed upon lines which have grown antiquated by the progress of medical science. It ought now to become the function of the scientist to re-model the whole system so as to fight disease at its source. The whole situation at the moment calls out for such a movement. On the one hand, there exists a widespread interest on the part of an awakened community in health questions, evidenced by recent legislation dealing with the health of school-children, with the health of the worker, with the sanitary condition of workshops, with the questions of maternity and infant mortality, and with the communication of infectious diseases. On the other hand, there is chaos in the medical organisation to meet all these new demands, and the ample means recently placed at the command of the nation and of municipal authorities are being largely wasted by overlapping and misdirection for lack of skilled leadership. Surely it is a time when those who have laid the scientific foundations for the new advances should take counsel together, assume some generalship, and show how the combat is to be waged, not as a guerilla warfare, but as an organised and co-ordinated campaign.

There are two essentials in the inception of this organised campaign against disease on a scientific basis. The first is to demonstrate clearly to the public mind that modern scientific medicine arose from the experimental or research method, that it was only when experimental observation of the laws of health and disease, in animals and man, commenced on an organised and broadcast basis that medicine and surgery leaped forward and the remarkable achievements of the past fifty years began. Also that it is only by the organisation and endowment of medical research that future discovery and advancement are possible. The second essential is to convince the public that a national system must be evolved placing medical science and medical practice in co-ordination, so that the discoveries of science may be adequately applied in an organised scheme for the prevention and treatment of disease. The method in which discoveries have been made in the past suggests an amplification and organisation along similar lines for the future, and the banishment of many diseases by public health work in the past suggests that it is more efficiently organised and wide-spread public health work in the future, extended from the physical environment to the infecting individual, that will be most fruitful in banishing other diseases.

If it be queried by anyone here, what has physiology to do with disease, it may be replied that the question comes at least fifty years too late. The methods evolved first by physiologists in experimentation upon animals have become the methods of all the exact sciences in medicine. Bacteriology is the physiology of the bacterium, and the study of protozoan diseases the physiology of certain groups of protozoa. Organo-therapy had its origin in physiology, and many of its most brilliant discoveries were made by physiologists, and all by scientists who used physiological methods. Serum therapy, experimental pharmacology, and the great problems of immunity all arose from the labours of men with expert training in physiology who branched out into practical applications achieved by the extension of the experimental, or research, method. The modern methods of medical diagnosis and the brilliant technique of contemporary surgery, what has opened the door to these but the experimental

method? From the days of the first successful abdominal operation to the present day, research in laboratory or in the operating theatre has pioneered the way, and the sooner this simple truth is known to all men the better for medical science. Every time any surgeon first tries a new operation there is in it an element of experiment and research of which the ethical limits are well-known and definable, and any person who logically thinks the matter out must see that it is the research method which has placed the science and art of surgery where it stands to-day. Exactly the same thesis holds for medicine. How could any physician predict for the first time, before he had tried it experimentally on animal or man, the action of any new drug, the effect of any variation in dosage, the result of any dietary, of the employment of any course of physical or chemical treatment, or of anything in the whole of his armamentarium? Yet the public are rarely told any of these wholesale truths, but are rather left to speculate that each medical and surgical fact sprang forth as a kind of revelation in the inner consciousness of some past genius in medicine or surgery, who, in some occult way, knew of his own certain foreknowledge what would be the definite effect of some remedy or course of treatment before he tried it for the first time on a patient, or perhaps had the ethical conscience and genuine humanity to test it on a lower animal before he administered it to man.

It may, in short, be taken as an axiom of medical science that everything of value in medicine and surgery has arisen from the applications of experimental research. Nor can future advance be made by any other method than the research method. It is true that accident may teach occasionally, as it did, for example, in the dreadful burns unwittingly inflicted on themselves and patients by the early experimenters in X-ray therapy and diagnosis. But accident is only the most blundering type of experimentation, and results obtained by its chance agency do not really invalidate the universal law that man only learns by experience or, in other words, by research. Research is, after all, only the acquisition of fresh experience by the trained expert, usually led on to his experiment by inductance from other known facts.

It has been said above that all that is valuable in medical science has been acquired by research; the converse may now be pointed out, that much that was valueless, dangerous, and even disgusting in medicine in earlier days was incorporated into the medical lore of the time, and often remained there for generations stealing lives by thousands, because physicians had not yet adopted the research method, and so based their practice upon ignorant and unfounded convention. It is noticeable in literature that up to somewhere in the beginning of the nineteenth century physicians and surgeons were often as a class looked upon by scholars and educated people with a certain amount of contempt. There were notable and fine exceptions in all ages, but, taken as a whole, the profession of medicine was not held in that high esteem and admiration that it is amongst all classes to-day. Take, for example, Burns's picture of Dr. Hornbook or Sterne's account of Dr. Slop in 'Tristram Shandy,' and similar examples in plenty are to be found in the Continental literature. The reason for the change is to be found in the comparative growth of medical science as a result of the research method. The physicians of those days were very often ignorant quacks employing the most disgusting and dangerous remedies, or methods of treatment, based upon no experimental knowledge and handed down in false tradition from ignorant master to ignorant and often almost illiterate apprentice. It is only necessary to peruse the volumes written on materia medica of this period to shudder at the nature of the remedies apparently in common use; the details are unfit for modern publication.

Even in the first half of the nineteenth century patients were extensively bled almost to exhaustion in a vast variety of diseases in which we now know with certainty that life would be endangered by such treatment and chance of recovery diminished. Thus, in a text-book published in 1844 by the Professor of Medicine in the most famous University in medicine of our country, and a physician in ordinary to her Majesty Queen Victoria, it is said that in the treatment of pneumonia 'the utmost confidence may be placed in general Blood-letting which should always be large and must almost always be repeated sometimes four or six times or even oftener. Blistering and purging, under the

same cautions as in the Bronchitis, are to be employed; and two other remedies have been much recommended. Opium, especially combined with Calomel, and the Solution of Tartar Emetic.' It seems scarcely credible to us nowadays that about this same period a low diet, blood letting, emetics, and purgatives were employed as a treatment in phthisis, yet such is the case. It is in keeping with the above, and in strange contrast to modern treatment, to find it recommended that if the patient cannot winter abroad he is ordered 'strict confinement within doors in an artificial climate, as near as possible to 60° Fahr., during at least six months of the year in Britain.' From the text books of medicine of this period, only seventy years back, instances of wrongful and even dangerous treatment in most of the important diseases might be produced. There is no basis of accurate scientific knowledge of physiology, bio-chemistry, or bacteriology underlying the visionary notions about disease. The real causes of the diseases being obscure, they are commonly set down to so-called diatheses or habits such as the 'hæmorrhagic diathesis' or the 'scrophulous habit.' Also, the action of infective organisms and the intimate relationships in regard to infection of members of the same family being unknown or forgotten, such 'habits' are erroneously set down as hereditary. When there is no other channel of escape the word 'idiopathic' is coined to cover the ignorance of the learned.

If now we pass onwards about thirty years in time, halving the distance between the above period and our own time, and consult an important text-book of medicine published in 1876 by a Fellow of the Royal College of Physicians, a physician and lecturer at a famous London Medical School, and a lecturer on pathology and physiology, we find that the progress attained by research in physiology, and physiological chemistry, and a growing belief in the possibility of infection in many diseases by the micro-organisms, now demonstrated so clearly in certain cases by Pasteur and his followers, have commenced to do their beneficent work in medical practice. The heroic bleedings and leechings and the scarcely less violent druggings with strong drugs have disappeared. The patient is less harassed by his doctor, who is more content to assist the natural processes of recuperation as his knowledge of applied physiology and hygiene teach him, rather than to thwart them and to lessen resistance as his predecessor often did a generation ago when he knew no physiology and less hygiene. Still, the comparison between the text book of even forty years ago and one of the present day shows a wonderful advance, all flowing from the use of the research method in the intervening years, both in knowledge of the origins and in the treatments of the diseases.

Time and space forbid going into details, but the whole of serum-, vaccine-, and organo-therapy were unknown, with the single exception of vaccination for variola. Enteric fever has been separated from typhus, but its etiology is still obscure, and, to a large extent as a consequence, the mortality from it is fifteen to sixteen per cent., or quadruple present-day figures, and it is one of the commonest of diseases. The cause of diphtheria is unknown, although it is now recognised as a 'contagious' disease, and as yet research in bacteriology has supplied no cure for it. The unity of the various forms of tuberculosis is unsuspected, the infecting organism is unknown, and, as a result, it is not even recognised as an infectious disease and heredity figures most strongly in a dubious etiology leading up to a vacillating treatment. Pneumonia is not recognised as due to a micro-organism, and is described as one of the 'idiopathic' diseases. The cause of syphilis, and its relationship to *tabes dorsalis*, and general paralysis are unknown, and generally it may be said that the causes of disease are either entirely unknown or erroneously given in at least three-quarters of the very incomplete list of diseases that are classified and described.

This, after all the centuries, was the doleful position of medical science in the year 1876, when suddenly light began to shine upon it, brought not by the agency of any member of the medical profession, but by a physiological chemist, and he was led to his great discovery, not in an attempt to solve some problem of practical medicine, but by scientific observations devoted to an apparently purely philosophical critical research into the supposed origin of life in a particular way.

It was the experimental or research method in bio-chemistry supported by physiological experiments on animals which in the hands of Louis Pasteur

laid the foundations of true knowledge, and transformed medicine from what has been described above into the glorious, living, evolving science that we possess to day.

The men who fought side by side with Pasteur in his famous struggle against orthodoxy in medicine as represented by the leading physicians and surgeons of the period between 1860 and 1880 were mainly chemists, biologists, and physiologists, such as Claude Bernard, Paul Bert, J. B. Dumas, Biot, Belard, and Sainte-Claire Deville in his own country, and Tyndall and Huxley in ours. A few physicians and surgeons of scientific training in France and England recognised the importance of his discoveries, such as Alphonse Guérin, Villemin, and Vulpian in his own country, while Lister in ours was already at work, had experimented widely and wrote his memorable letter of congratulation to Pasteur in 1874, informing him of the work he had been doing in introducing antiseptic surgery in England during the preceding nine years. Against this intrepid little band of experimental scientists were massed all the batteries of orthodox medical nescience served by the distinguished physicians and surgeons of the time; but truth is mighty and must prevail. Davaine applying Pasteur's principles in a medical direction had found out the bacterial origin of anthrax, and although he was violently attacked by oratorical arguments in opposition to experimental proofs, and accused, as many physiologists are to-day, of having 'destroyed very many animals and saved very few human beings,' his facts held fast, and combined with the later experiments of Koch and of Pasteur, not merely established the etiology of anthrax as we know it to-day, but gave a support and forward growth to that new-born babe, Bacteriology, which without such animal experiments could never have grown into the beneficent giant that it is to-day in all its glorious strength for the weal of humanity.

Pasteur himself meanwhile was hard at work in the small ill-equipped laboratory of Physiological Chemistry of the Ecole Normale at Paris, from which the fame of his discoveries began rapidly to spread and shed a new light forth on the medical world. Pasteur at this stage had already largely rehabilitated the national prosperity of his own country by his successful researches on silk-worm disease and on fermentation maladies and the diseases of wines. All this effect upon national industries, it is to be noted, followed on from an inquiry of apparently no practical importance on spontaneous generation. He now turned his genius towards disease, there also utilising the same discovery arising from a research that contained at first sight no possible applications to disease, and the remainder of his life was devoted to the extension of these studies. The subsequent history of this discovery is the science of Bacteriology with all its ramifications and manifold applications in industry, in agriculture, in medicine, and in public health, investigated by the experimental method by thousands of willing workers all over the civilised world. Who but the ignorant Philistine, who knows not what he prates about, can deny the profound influence of animal experimentation, and the philosophic application of the principle of research upon the history of the world?

Let us now, from the vantage-point of the present, look back at the past and glean from the study of the manner in which this science took origin some knowledge to guide us, first, as to how research may be fostered and encouraged in the future, and secondly, as to how the results of research may be applied for social advantage.

The first and perhaps the finest thought of all is that research must be pursued with the highest ideals of the imaginative mind apart from all desired applications or all wished for material advantages. If we might personify Nature, it would seem that she does not love that researcher who only seeks her cupboard, and never shows her finest treasures to him. She must be loved for her own beauty and not for her fortune, or she will ne'er be wooed and won. Not even the altruistic appeal of love for suffering mankind would seem to reach her ears; she seems to say: 'Love me, be intimate with me, search me out in my secret ways, and in addition to the rapture that will fill your soul at some new beauty of mine that you have discovered and known first of all men, all these other material things will be added, and then I may take compassion on your purblind brothers and allow you to show them these secret charms of mine also, so that their eyes may perchance grow strong, and they, too, led

hither by you, may worship at the shrine of my matchless beauty.' By all the master discoveries in all the paths of science, Nature is ever teaching us this great doctrine to which we have closed our ears so long. She tells us the creation of the world is not finished, the creation of the world is going on, and I am calling upon you to take a part in this creation. Never mind that you cannot see the whole, love that you see, work at it, and be thankful that I have given you a part to play with so much pleasure in it, and so doing you will rise to the highest ideal.

This is religion with thirst for knowledge as its central spring; does it differ much from those aspirations which have made men of all nations worship throughout all the ages? Anthropology teaches us that the religious system of a race of men gives a key to their advancement in civilisation. If this be so, growth in natural knowledge must elevate our highest conceptions, furnish purer ideals, and give us more of that real religion that is to be found running so strongly in the minds of great individuals such as Isaac Newton, Michael Faraday, Louis Pasteur, Auguste Comte. A great man may be strongly opposed to the orthodox creeds of his day, he may even sneer at them, he may be burnt at the stake by their votaries, and yet be a man of strong religious feelings and emotions which have furnished the unseen motive power, perhaps unsuspected even by himself, that leads to a whole life of scientific heroism and enthusiasm.

The practical lesson for us to learn from all this is that we must consider research as sacred and leave it untrammelled by fetters of utilitarianism. The researcher in functional biology, for example, must be left free to pursue investigations as inspiration leads him on any living structure from a unicellular plant to a man, and must not be expected to devise a cure for tuberculosis or cancer. In his research he must think of something higher even than saving life or promoting health, or he is likely to prove a failure at the lower level also.

As an example of the wrong attitude of mind towards science, there may be taken the point of view of those utilitarians who complain of the amount of time and discussion at present being given to the problem of the origin of life. These wiseacres with limitations to their brains say 'that is an insoluble problem, we shall never get to the bottom of it, let us simply assume, since it is here, that life did originate somehow, and, taking this as an axiom, proceed to some practical experimental problem; the origination of life does not lend itself to experimental inquiry.'

Now it is, strange to say, just those problems that appear most insoluble upon which the inquiring type of mind loves to linger and spend its energies, and, although the problems never may be solved, the misty solitudes to which they lead are glorious and the fitful gleams of half-sunshine that come through are more kindling to the senses of such men, than the brightest sunshine on the barest of hills. It is here, and in such quests, that the biggest of human discoveries are made, and not all of them are in natural science alone.

The search after the mystery and origin of life had profound influence in raising man from a savage to a civilised human being, and is found as an integral part in all religions above a certain level of savagery. Much of the system of morals and ethics of civilised nations is unconsciously grouped round this problem, and we owe the existence of that social conscience which makes each of us our race's keeper to our interest in the nature of life, and our ties with other lives. Leave such a problem alone and attend to routine researches! Why, the human intellect cannot do it, such problems compel attention! What, it may be asked, was it that started all this routine research in biology, in favour of which we are asked to abandon the search after the origin of life? The routine research would not exist, but for a discovery made in investigating whether life originated in a certain alleged way.

If the whole science of bacteriology emerged from a proof that a certain alley did not lead to the origin of life, how much more glorious may that knowledge become that finally leads us to this goal, or even one step onward in our true path towards it. The search after the origin of life is an experimental inquiry, it leads straight to research, that is all the physicist or chemist demands of a theory, it should be enough for the biologist. We who search for this are not occultists whatever may be said of those who oppose.

Let us then learn to have a catholic spirit about research, and try to convince the world that it commands devotion not merely because of material advantages which it may bring, but because it is the most lovely and most holy thing that has been given to man. So may we clear the fair name of Science of the false charge of materialism that is so often brought against it by those who do not know and judge Science purely by mechanical inventions.

Next let us consider the applications of scientific discovery and see if we cherish aright the gifts of the fairy godmother, for her gifts are dangerous if wrongly used. Consider, if this be doubted, the enormous advantages given by mechanical and chemical contrivances in producing the material comforts necessary to civilised human existence, and then turn your eyes to the reeking slums of our great cities. It is clear that natural science cannot go on successfully alone, it must take sociology with it if our world is to be a better world to live in because of the gifts brought by scientific discovery.

Nor is the ideal and the outlook different in the least from that given above for pure research, when we come to consider its applications, the same high spirit must prevail in all our endeavours, or we shall defeat our own ends and miserably fail. Selfishness here, as everywhere, must recoil on the culprit, who only deadens his own soul. Health is needed not to grow wealthy or to prolong to greater length a 'lingering death' as Plato puts it, but to fill life with happiness, and beckon the bold and adventurous forward to higher things. Here we must copy Nature's own plan and take care of the race as a whole instead of spending our energies upon single individuals or favoured classes. Nor need anyone fear that any individual or any particular class in the community is going to suffer from the adoption of the true scientific attitude towards disease. The penalty taken by Nature on the more comfortable classes, who have hitherto enjoyed the greater share in government for allowing the existence of poverty, disease, and slumdom, is to utilise this neglected area as a culture-ground for diseases, which invade the classes above. Nature is still at work creating, still conducting evolution at the highest level, and disease is at present the tool with which she is working. So long as those poverty-stricken slums are allowed to remain, just so long is she grimly prepared to take her toll of death and suffering from those who ought to know how to lead on and do it not. The disease and the crime below are to the social community what pain is to the individual, and just as the special senses become more highly organised and sensitive as the nervous system becomes more highly developed, so as the civilisation of the community intensifies does the public conscience awaken to forms of mischief and crime in one generation that were unsuspected in a previous one. So social evils become intolerable and finally are removed. How then are we employing our knowledge as to the causation of disease to the public problem of its removal or abatement?

In regard to the physical environment much has been done during the past generation towards applying the laws of hygiene, as is shown in the sanitation of our great cities, and especially in regard to the question of water-supply. It is good, for example, that Glasgow goes to Loch Katrine for her water-supply, Manchester to the English Lakes, and Liverpool to the Welsh hills. Each of these great cities carries for many miles the pure distillate of the hills to its million of inhabitants. It has cost much in pounds sterling, though not more than if each family had a pump in its back-yard. On the other hand, think of the disease and suffering and death prevented, enteric fever almost gone where thousands would have died of it, and tens of thousands been debilitated, and these of the best of the citizens, for disease is no eliminator of the unfit. Think of all this, and then say, Did it not pay these great cities to bring the pure water from the lakes in the hills?

But why do these good cities content themselves to allow their little children at a most susceptible age to be supplied still with milk which contains the bacillus of tuberculosis in so large a percentage as five to ten per cent.? And why does the law of the land prevent these Corporations from searching out tubercular cows in all the areas supplying them with milk? If it is part of the business of a municipality to see that its citizens have a pure water-supply, why should it not also be allowed to see that they have a clean milk-supply?

Long ago the power to make the lame to walk was regarded as a divine gift.

When is mankind going to awake to the fact that Science has placed this gift in its hands? Much more than half of the lame and spinally-deformed children in our midst are in that condition because of infection of joints or spine with the bacillus of tuberculosis. By open-air hospitals and open air schools we seek and succeed in curing a percentage of them, but how much better it would be if we took the fundamental problem of tubercular infection in hand and prevented them from becoming lame and deformed?

There is at present on foot in England a great scheme to enable the blind to read, and it deserves our support because it is our fault that these people are blind. The sad fate of the man born blind appeals to all kind hearts; but men are not born blind, they become blind within a week or two of birth because of an infectious disease contracted from the mother at birth. Science knows and has taught the world how this blindness can be quite prevented, and it is because of our faulty organisation for attending to maternities amongst the poor that these people are blind. By proper organisation practically all blindness arising at the time of birth can be prevented. Why is it not done? Thus our modern Science can make the blind to see and the lame to walk, but it is so manacled by ancient ways and customs that it is left powerless, and so there are these maimed and darkened lives of innocent people, and they are left partially burdening the community which has only its own folly to blame for the whole stupid position.

Let us consider lastly a disease which collects the last toll from one-seventh of humanity, and debilitates and enfeebles the lives of many whom it does not entirely destroy. At all ages, in infancy, in the prime of life, and in life's decline, it snatches away the best of our fellow-men. How are we organising our campaign against tuberculosis? Bacteriology has taught us that it is an infectious disease and has isolated the organism. It is an undoubted fact, proven to the hilt by many inquiries and observations, that infection passes from individual to individual. How is this knowledge being applied, and how are we attempting to stem the tide of infection? In the United Kingdom alone about 70,000 persons die annually of the disease, and all over the civilised world the total death-roll of human kind annually from tuberculosis probably does not fall short of a million souls. This tide of infection is kept up, year in, year out, and every 70,000 dying annually in Britain must have infected 70,000 fresh victims before they themselves are carried away. Can it not be stopped, this foul tide of infection? What is being done to stop it? Sanatoria are being provided for the early cases, the bad and most infectious cases are largely being left alone to sow infection broadcast and then die. This is the chief means being used at present to stop the tide. The early non-infectious case is deemed the more important to look after, and the well-advanced, open, thoroughly infectious case is left to itself to infect others and then to die. This is the condition of our public health attitude in regard to tuberculosis. It is a travesty on the application of all biological laws, and in direct opposition to all laws of racial preservation. Industrial conditions have produced an artificial environment and enhanced the chances of infection by the organism of this disease; it should be our plan to copy Nature's method and safeguard the interests of the community, and to do this we must proceed on the plan of separating the source of infection—that is to say, the infectious individual from the sound individual. This is done with success in the case of small-pox and cholera, and this plan has eradicated hydrophobia; why should it not be carried out in the case of tuberculosis? Under present conditions men, women, and children are going on unwittingly infecting one another by the thousand with tuberculosis in school, workshop, and home, and we who know it take no public action and raise no clamant outcry against it. It is of more value to the community to isolate one pauper far advanced in tuberculosis than to send ten early cases to sanatoria. This disease must be stopped at its source as well as dealt with on its course. No disease has ever been eradicated from a community by discovering cures for it, and none ever will; many diseases have disappeared because their sources have been cut off.

Let us be scientific, let us search out the truth; having found it, let us act upon it, and let us conceal nothing that is true.

The following Papers and Reports were then read :—

1. *The Mammary Gland.* By Professor Sir Edward Schäfer, *F.R.S.*

2. *The Physiology of Cerebro-Spinal Fluid.* *By* Professor W. E. Dixon, *F.R.S., and* Professor W. D. Halliburton, *F.R.S.*

3. *Pseudo-Motor Action and Recurrent Sensibility.* *By* Professor W. A. Osborne.

(1) If the hypoglossal nerve is cut and some days afterwards stimulation is applied to the distal end of the freshly cut lingual, a motor response in the tongue muscles is obtained. This frequently described pseudo-motor action can be readily demonstrated. Attempts have been made in the present research to obtain this response in other regions such as the facial muscles innervated by branches of V. and VII., but without success. Occasionally in man there is a moderately thick connecting loop between the lingual and hypoglossal. This is described as normal in the anatomy of the horse and dog, but numerous dissections have failed to give one instance, so that histological examination is unfortunately lacking.

(2) Stimulation of the distal facial nerve may give rise to reflex responses including rise of blood-pressure. This effect is obtained only very seldom. When given it can be shown to be due to sensory impulses arising in the tense fibres of the contracting facial muscles. It vanishes on very light curarisation, and cannot, therefore, be due to a definite union between facial and trigeminal fibres.

4. *Central Neural Response to Peripheral Neural Distortion.* *By* Professor W. A. Osborne *and* Basil Kilvington, *M.S.*

When two nerve-trunks such as the popliteals are crossed the co-ordination is rapidly learned after regeneration has set in. We have shown that the central changes required in the new conducting mechanism are well established even in the lowest levels of the central nervous system. We have also shown that if there is considerable axon bifurcation in the peripheral nerve-trunks, and if fibres of the same neuron traverse antagonistic routes (*e.g.*, flexor and extensor), good co-ordination is not acquired. In our latest experiments the central phrenic on one side was sutured to a distal cord of the brachial plexus. When regeneration occurred a restricted portion of the scapular muscles was seen to be rhythmically excited in synchronism with the diaphragm. The action of the contracting fibres on the limb was very slight, producing in the anæsthetised animal a just detectable abduction.

In eleven months' time no change could be observed in the amount of movement of the affected muscular fibres. Support and progression had never been interfered with, and presumably for this reason co-ordination was not acquired. The operation gave an interesting method for observing inhibition in a restricted number of muscular fibres. During expiration the exposed surface of the affected portion of the deltoid was seen to bulge slightly through pressure of adjacent tonic fibres. During asphyxia the visible contracting area enlarged, encroaching upon portions of muscle surface not previously affected.

5. *Evidence of Co-ordinate Action in the Circulatory System.* *By* E. H. Embley, *M.D.*

Firstly, the results of experiment upon venous pressures appear to indicate a nervous mechanism controlling venous tension. Secondly, with certain exceptions cardiac and venous innervations seem to be co-ordinated—the cardiac vagi with the venous constrictors, and the cardiac accelerators with the venous

dilators. Thirdly, with certain exceptions, cardiac and arterial innervations appear co-ordinated—the vagi with the dilator, and the accelerators with the vaso-constrictor mechanisms.

Evidence of venous innervation:—

(1) Venous pressure in asphyxia rises either simultaneously with, or subsequent to, the rise, and after the fall to zero of arterial blood-pressure.

(2) Venous pressure rises either simultaneously with, independently of, or it fails to rise with, the rise of arterial blood-pressure upon the intravenous injection of adrenalin, epinine, or pituitary. Moreover, it may rise and fall and rise again during the period of raised arterial pressure upon intravenous injection mentioned.

(3) During syncopal fall of arterial blood-pressure the bowel volume markedly diminishes. This occurs whether the animal be prone or supine, and whether the heart's rate be greatly or slightly retarded. Such fall in arterial blood-pressure is accompanied by a rise in venous blood-pressure and arterial vaso-dilation, as is well shown in the syncope induced by clamping the brain arteries, in which case the heart's rate is practically constant. The only interpretation which seems possible is that of venous constriction.

The possibility of interpreting these results as due to varying intra-abdominal tension from muscular action, or to alterations in cardiac output, or to blood displacements or changes in arterial tension, was found to be inadequate to explain the phenomena. Venous innervation seems to be the only interpretation possible.

The frequent association of vagus inhibition of the heart—as represented by a retardation of rate ranging from moderate slowing to actual heart-stop—with a rise of venous pressure, cannot be ascribed to dislocation of blood as a result of diminution in the heart's output, because it occurs whether the arterial blood-pressure be falling or rising. Similarly the fall of venous pressure constantly associated with accelerator action cannot be ascribed to dislocation of blood by arterio-constrictor retention, since it occurs whether the arterial blood-pressure be low or rising. Moreover, the venous blood-pressure may be found both high and low in a single tracing, in which, throughout, the arterial blood-pressure is high, but in which vagal action is temporarily replaced by accelerator, during which temporary period the venous pressure falls and remains low till vagal action is restored. It points to co-ordinate innervation, and further to reciprocal relations between the vagi and venous dilators on the one hand, and the accelerators and venous constrictors on the other.

Examination of a larger number of blood-pressure tracings shows a constancy of co-ordinate innervation of the cardiac accelerator with vaso-constrictor, and again of the cardiac vagus with vaso-dilator mechanisms. They furthermore indicate a reciprocal relation between these groups. There are accountable exceptions in asphyxia, adrenalin and other intoxications, depressor nerve excitation, a depression of the vagi, &c. Syncopal fall of arterial blood-pressure with cardiac slowing is constantly associated with vaso-dilation, whilst sudden rises in arterial blood-pressure show more or less the incidence of accelerator rhythm, which may or may not be due to increased secretion of the suprarenals.

6. *Artificial Collateralisation as applied to the Abdominal Aorta.* *By* Basil Kilvington, *M.S.*

Cases have been found post-mortem where the abdominal aorta has been completely occluded, yet life has been possible. This has been caused by certain pathological conditions which act gradually.

An attempt was made to imitate this gradual occlusion by ligaturing the abdominal aorta in two stages. The first operation consisted in partly obstructing the aorta by a silk ligature applied a short distance above the bifurcation into the two iliac vessels. It was impossible to gauge accurately the narrowing, but, as a rough test, the ligature on the aorta was tightened till the pulsation was just, though definitely, perceptible to the finger applied where

the common femoral crosses the ramus of the pubes. The animal recovered from this with few symptoms, and two or three weeks later the aorta was completely blocked by a second ligature applied just central to the first. In every instance the animal survived this, and after recovering from the operation ran about as usual.

In the deep epigastric the flow was reversed, *i.e.*, the blood moved from the umbilicus through the superior epigastric downwards. The main collateral supply came, however, from the anastomoses between the two circumflex vessels (branches of the femorals) with the sciatic and lumbar arteries about the upper end of the thigh. Blood-pressure tracings from the femoral artery displayed typical damped oscillations similar to those obtained from a normal artery when the connecting tube to the manometer is partly clamped. Obstruction of the aorta above the iliacs, produced immediately by a single ligature, is practically always fatal.

It is intended to utilise this method in ligature of vessels which is attended by grave complications owing to poor collateral blood-supply. An ideal instance would be in the case of the abdominal aorta for an aneurism situated below the renal vessels. Other less critical examples would be in the case of the common femoral or popliteal arteries. This method might prove more suitable than plastic operation on the aneurism itself.

7. *Sixth Interim Report on Anæsthetics.*

8. *Report on the Binocular Combination of Kinematograph Pictures.*

9. *Report on Calorimetric Observations on Man.* See Reports, p. 238.

10. *Report on the Ductless Glands.*—See Reports, p. 237.

11. *Report on the Effect of Low Temperature on Cold-blooded Animals.*—See Reports, p. 241.

12. *Report on the Physiological and Psychological Factors in the Production of Miner's Nystagmus.*—See Reports, p. 241.

TUESDAY, AUGUST 18.

Discussion on Anæsthetics.

(i) *Opening Remarks.* *By* Professor A. D. Waller, *F.R.S.*

Professor Waller, after a complimentary reference to the epoch-making work on chloroform anæsthesia by Professor Martin and Dr. Embley in Melbourne, discussed some of the outstanding features in connection with the dangers of the administration of chloroform. He emphasised the rule that the amount of chloroform administered must not be above 2 per cent. nor below 1 per cent. to be effective. Any apparatus used must be contrived with the above object in view.

Professor Waller considered that the fear of chloroform is excessive at the present day, but that the danger is very small if not more than 2 per cent. is administered. Idiosyncrasy is of some importance, but most cases of accidents arise from the giving of too much chloroform, and not from the use of too little. He demonstrated a portable chloroform apparatus which admirably fulfils the conditions desired.

(ii) *Remarks by* Dr. E. H. Embley.

The employment of the regulating inhaler is certainly a progressive step in the administration of chloroform. Anæsthesia so induced is not attended by the great nervous excitation which so frequently accompanies the administration of chloroform by the drop method. This with the attendant exaggeration of respiratory intake, so raising the tension of the chloroform in the arterial blood for the time, constitutes an important contributing factor to the causation of primary syncope. Moreover, the uniformity of the resulting anæsthesia by the regulating inhaler is quite remarkable. It is free from the oscillations in depth of narcosis so often observed in the drop method.

Yet it has not been adopted in Melbourne. This appears to be due to the frequent necessity of transgressing the 2 per cent. boundary line of safety and of employing 2·5 or 3 per cent. concentration to induce anæsthesia in reasonable time; also because in the light degree of narcosis maintained, depressor reflexes appear to occur much more readily than in the deeper narcosis of the older method; but more especially has it been abandoned on the grounds of the toxicity of chloroform, however administered. Professor Waller has stated that the relative pharmacological potency of chloroform and ether is as 10 to 1. (I have found that 2·2 per cent. chloroform vapour is nine times as depressing to the myocardium as is 19·1 per cent. ether, and 40 times as depressing as is 10 per cent. ether.) This is the relative toxicity, and the actual reason for the abandonment of chloroform. More especially is this the case since the adoption of the method of mixed ether narcosis, that is, the preliminary use of morphine and other alkaloids. One practically never hears of reflex, or the other form of syncope, in mixed ether narcosis.

I cannot recall statistics of mortality from chloroform syncope, but I think Leonard Hill found, some years ago, that it represented about 90 per cent. of the total mortality. I have several experimental records of this form of death from chloroform. I find the mechanism of chloroform syncope to be the combined exaltation of the cardio-inhibitory and arterio-dilator nervous mechanisms —the heart is arrested and the arteries dilated. Whether the heart will free itself from the inhibition depends upon the degree of responsivity remaining in the heart when the inhibition occurred; also probably upon the extent of the compensatory rise of venous blood-pressure. *If the vagus terminals give out early the heart frees itself.* Venous pressure always rises in syncope. In chloroform syncope the rise is proportional to the degree of general intoxication. A high venous pressure in the cavities of the right side of the heart and in the great veins adjacent seems to exert a stimulus towards the restoration of the heart's rhythm. Artificial respiration appears to exert a similar stimulus, it also exerts a stimulus towards restarting the respiratory rhythm. The rise of venous pressure in the right heart cavities may be augmented by gravity—that is, by turning the patient so that the head is on the floor and the feet up, and by aspirating the splanchnic bed in doing artificial respiration.

Deaths from excessive intoxication by chloroform, apart from cardiac inhibition—that is, deaths from general paralysis of the cardio-vascular musculature and depression of the nervous mechanism of the circulation—must be very rare. Such cases are thought to occur during the course of anæsthesia—that is, after the more dangerous period of induction. In most instances the respiration fails first, and then any further accession to the tension of chloroform in the blood is arrested. Artificial respiration then suffices to restore the blood-pressure. When such deaths do appear to occur the final stroke is probably always cardiac inhibition. The excitability of the vagi, which had become depressed by the chloroform after the initial period of excitation, is again exalted by the bulbar anæmia consequent upon the low blood-pressure. It is extremely difficult to

kill an animal with chloroform after the vagi are cut. The protective use of atropine with the same object as vagotomy is sound in principle, but it has not been availed of by anæsthetists chiefly on account of its disturbing effect on the pupil of the eye, thereby misleading them as to the depth of narcosis.

(iii) *Resuscitation in Threatened Fatalities during the Administration of General Anæsthetic Agents. By* E. H. Embley, *M.D.*

Deaths under anæsthetics by no means occur from a common cause nor under the same pathological conditions. They may be arranged in four groups :—I. Syncopal. II. From excessive tension of anæsthetic in the body. III. Shock or exhaustion. IV. Pre-existing pathological states and various accidental conditions.

I. Syncopal.—Such cases occur early in the administration. Respiration ceases either just before, at the same time as, or just after the heart—mainly in consequence of the low or absent arterial blood-pressure. The cessation of pulse and the loss of colour from the face are sudden. The heart is arrested and the arterioles relaxed by inhibition, not by paralysis. The venous blood-pressure is high. Reflex syncope may happen at a later period in the administration, but it occurs mostly under light narcosis.

II. Excessive narcosis.—Respiration invariably ceases before the circulation. The loss of colour of face and the progressive diminution in pulse volume and tension are relatively much slower than in syncope. In chloroform narcosis the respiration has been progressively diminishing up to the time of stoppage. The cardio-vascular neuro-muscular mechanism is paralysed, and both the venous and the arterial blood-pressures are low.

III. Shock or exhaustion, whether previously existing or incurred in the operation, is indicated by a progressively increasing heart-rate (generally excepting that of old people), with diminution in pulse tension and volume. Loss of face-colour and diminishing efficiency of lung-ventilation progress similarly. The vaso-motor system is chiefly concerned in the circulatory failure. The experimental evidence available up to the present indicates exhaustion of the vaso-motor central mechanism, and of the secretory function of the adrenals, as the causative factors of the circulatory depression in shock. The venous and arterial blood-pressures being low, the heart cavities are imperfectly filled and the coronary blood-supply inadequate for the heart's needs. Respiration is defective and the temperature low.

IV. Drowning by blood, pathological fluids, vomit, &c. Laryngeal obstruction by spasm, foreign bodies, vomit or blood. Respiratory paralysis in cases of cerebral pressure. Œdema of the glottis. Retropharyngeal abscess. Ludwig's angina. Septic degenerations. Reflex syncope from surgical afferents, &c.

I. Syncope.—The aim in treatment is that of cutting short the inhibition. Three methods are of value for this purpose :—(*a*) Raising the blood pressure in the right cavities of the heart and in the great veins adjacent. (*b*) Artificial respiration. (*c*) Rhythmic manual compression of the heart.

(*a*) Raising the venous blood-pressure in the heart and adjacent veins. Some evidence seems to indicate that heightening venous tension in these parts is the cause of the normal cardiac rhythm. This pressure is high in syncope, but in the syncope of anæsthetics the rise of pressure is more or less impaired. It may, however, be supplemented by gravity when the patient is inverted head down, and by the aspirating effect of artificial respiration. A good head of pressure, at the right side of the heart, furthermore affords the requisite blood for filling the arterial system when inhibition ceases.

(*b*) Although artificial respiration cannot oxygenate the blood with the circulation arrested, it exercises the afferent impulses whereby reflexly the respiratory rhythm is regulated by alternately inflating and compressing the pulmonary alveoli, and it assists in helping to restart the heart by the precordial pressure of the expiration movements, besides assisting to raise the venous pressure in the great veins adjacent to the right heart.

(*c*) Rhythmic manual compression of the heart through the diaphragm.—When the above measures fail this should not be neglected, though it entails opening the abdomen. Experimentally it invariably succeeded in restarting a

heart arrested by inhibition, but it always failed in cases where the heart was irresponsive to stimuli, from excessive narcosis. In such cases as these, and in those in which the heart was pathologically impaired beforehand, was syncope fatal.

The use of strychnine, atropine, ether, amyl nitrite, &c., is irrational.

II. Excessive narcosis.—When the heart has ceased from this cause no remedy will restart it. Experimentally the tension of the anæsthetic in the myocardium may be rapidly reduced, so as to admit of restoration of function, by the perfusion of isotonic salt solution through the coronary arteries; but this has no clinical value in consequence of the pulmonary œdema which ensues and the difficult surgical technique entailed. The indications for treatment are:—(1) Elimination of the anæsthetic as rapidly as possible. (2) Raising the blood-pressure in the right cavities of the heart and in the adjacent veins.

(1) Elimination.—In less severe intoxication, with respiration still continuing, it is only necessary to withdraw the anæsthetic mask. Where respiration is feeble or has ceased, artificial respiration is demanded. This not only eliminates the anæsthetic, but it oxygenates the blood and assists in raising the venous blood-pressure in the great veins at the right side of the heart.

(2) Raising the venous pressure at the heart.—Inversion into the head-down position and artificial respiration, as for syncope. If the heart has not ceased, recovery is relatively rapid. Strychnine is not harmful, but it is not indicated. Amyl nitrite and ether are both harmful. Fatal excessive narcosis is often finally accompanied by cardiac inhibition.

III. Shock.—The same indications exist for raising the blood-pressure in the right cavities of the heart and the veins adjacent as for I. and II. This is attained by inversion into the head-down position. The body-heat must be maintained and warm oxygen inhalations used. The employment of warm saline injections or infusions is not indicated unless in collapse from great loss of blood. Otherwise the rise of arterial and venous blood-pressure is soon lost in consequence of its rapid exudation into the surrounding tissues. Ergot and pituitary are of use in the mild forms, but where help is urgent they fail. Adrenalin and epinine, however, always raise both venous and arterial blood-pressure, but only temporarily unless it be given by continuous flow into the vein and not of greater concentration than one in 500,000, with the pulse used as a guide. The flow should be reduced if the pulse-rate falls to 60 per minute. The more severe the shock the greater is the care necessary to guard against vagus inhibition of the heart or against ventricular fibrillation from excess of adrenalin.

IV.—In cases of drowning the patient should be inverted head-down, and, if the fluids have entered the bronchus from below, the sound side should be preserved from flooding by promptly turning it uppermost. When both sides are flooded a tube should be inserted through a laryngotomy opening and the blood or fluid aspirated by the mouth or other ready means. Laryngeal spasm or obstruction may be relieved by the finger or sponge cleaning out the glottis. An artificial cough, induced by sudden bilateral compression of the thorax, will often expel material or open a larynx closed by spasm. Respiratory failure in operations in cases of cerebral compression may be obviated by a preliminary injection of atropine, otherwise artificial respiration must be performed through the operation. Light narcosis is used throughout these operations. Cases of œdema of the glottis, retropharyngeal abscess, and Ludwig's angina are very dangerous for general anæsthesia, and should be operated under local anæsthesia only. Reflex syncope cases are treated as syncope. Cases known to be liable to depressor reflexes should receive a preliminary injection of morphine and atropine, and be given ether

(iv) *Observations on a Case of Delayed Chloroform Poisoning.*
By Professor R. F. C. Leith.

This form of poisoning denotes a persistent and generally fatal intoxication which comes on at varying intervals (from a few hours to many days) after the chloroform narcosis has passed off, and closely resembles the pyogenic forms. It is a rare condition, the number of cases recorded since its first recognition

by Caspar in 1850 hardly exceeding fifty. The present case occurred in the General Hospital, Birmingham, in October 1913, in a boy aged eight, admitted under the care of Mr. Woodman. He was a healthy lad who had been run over by a light motor van. Laparotomy disclosed a rupture of the liver about two inches long and one and a half inch deep close to the fissure of the gall bladder. The abdominal cavity contained about two pints of blood-stained fluid. There was no other lesion. Neither the shock nor the amount of blood lost was serious. The operation lasted half an hour, anæsthesia having been initiated by chloroform and ether mixture for four minutes, and maintained thereafter by ether alone. The total amount of chloroform administered did not exceed two drachms. He recovered completely from the narcosis and did well for a time, but symptoms suggestive of septic poisoning supervened, and he died in about forty hours. On post-mortem examination no peritonitis or other inflammatory condition was found, nothing, in short, beyond the rupture and a markedly fatty state of the liver, to which the fatal toxæmia could be ascribed. Microscopically an intense degree of fatty degeneration combined with a peripheral fatty infiltration existed in every lobule throughout the organ, but somewhat more severe in the neighbourhood of the rupture. Though there was no actual cell necrosis, the nuclei mostly staining well, the cytoplasm was markedly degenerated and had lost its power of retaining fat within its intimate structure. Its 'masked' fat had become visible in the form of numerous fine granules and globules within the hepatic cells, particularly those in the inner parts of the lobules—a condition of true fatty degeneration. Towards the peripheral parts, on the other hand, the fat globules were fewer and larger—an infiltration instead of a degeneration. The peripheral cells had retained their normal function of infiltrating fat, and a larger supply being available, had produced a high degree of fatty infiltration. All the fat present readily absorbed the ordinary stains for fat, and, by giving the typical red-colour with Nile blue, was shown to be neutral fat. In short, the condition of the liver, while resembling phosphorus poisoning most closely, presented appearances similar to those resulting from the action of other poisons, notably those of the pyogenic organisms and of acute yellow atrophy. All these poisons damage the liver cells, producing granular and fatty degeneration often combined with fatty infiltration, if their intensity be not too great. But they all differ from delayed chloroform in that their results are certain, provided that the dose be sufficient, whereas in the case of chloroform the results are extremely capricious, hardly arising even in one case for every thousand in which they do not appear. That is, if the chloroform be inhaled, but if given by the mouth or subcutaneously, they follow as certainly as after the other poisons. This anomaly is not at present capable of explanation, except on the assumption of an individual idiosyncrasy, and, though individual susceptibility to certain drugs is an admitted phenomenon, it can hardly be regarded as satisfactory. A better explanation may be forthcoming with an increase in our knowledge of the physiological action of chloroform. The severe and persistent vomiting which is such a characteristic symptom of the disease, and the hæmorrhagic inflammation of the gastric mucosa sometimes found, suggest that either chloroform or a toxic derivative thereof is secreted into the stomach and absorbed by the portal vein, but, even if true, it does not explain the capricious incidence of the disease. In a considerable number of the recorded cases, the liver has already been damaged by pre-existing abdominal or other disease, and the chloroform may be held to act as the last straw, but in others, as in the present case, it has been healthy. But it is not difficult, as experiments show, to produce, and that rapidly, an extreme degree of fatty change within the liver under a variety of conditions, and it is possible that some other factor than the chloroform, not yet recognised, may be the cause of the disease. On experimental grounds alone it seems certain that ether cannot cause it. Though as yet unexplained, it seems probable that delayed chloroform poisoning does exist as a separate entity, and, though rare and fatal in its severer forms, may be not uncommon and transient in milder forms.

Professors Osborne and Milroy also took part in the Discussion.

The following Papers were then read :—

1. *The Problem of the Visual Requirements of the Sailor and the Railway Employee.* *By* Dr. JAMES W. BARRETT, *C.M.G.*

See Reports, p. 256.

2. *The Mechanism of Micturition Control in Human Beings.* *By* Dr. S. SEWELL.

A number of cases of lesions of the spinal cord above the lumbar enlargement, in the lower lumbar region, and in the sacral region were described, illustrating the various effects upon the control of the function of micturition produced by lesions at these various levels. In lesions of the sacral cord, or *cauda equina*, reflex micturition is not established even after fifteen years, patients still maintaining absolute retention and requiring regular catheterisation, possibly as a result of the still active lumbar innervation of the sphincter. Cases of supra-sacral lesion develop reflex incontinence of urine of which they are unconscious, thus suggesting that the spinal arc is sufficiently well laid down in human beings for the maintenance of this primitive function.

3. *The Biochemical Significance of Phosphorus.* *By* Miss HILDA KINCAID, *D.Sc.*

The research can be divided into two parts :—

I. The general zoological significance of phosphorus.
II. Its peculiar biochemical significance in Victoria.

I. The fact that the framework of the lower animals is largely $CaCO_3$ and that of the higher animals $Ca_3(PO_4)_2$ suggested that there might be a very gradually increasing use of $Ca_3(PO_4)_2$ for framework purposes as we ascend the animal kingdom. Analysis of the exoskeleton of each class of invertebrates showed the very interesting fact that the phosphorus content increases steadily as we ascend the evolutionary scale, though never at any time large in the Invertebrata.

When we come to the endoskeleton of the vertebrates, however, there is a sudden jump in phosphorus content, which remains practically constant throughout the vertebrate group.

On the other hand, analyses showed that the phosphorus content of nerve tissue and muscle has a surprising uniformity throughout the whole animal kingdom.

II. It has been realised for some time that Australian soils are lamentably poor in phosphorus, some even as low as 47 parts of phosphoric acid in 100,000 parts of soil. Experiments were made with a view to determining whether the deficiency in phosphorus is also a feature of the products of the soil, viz., cereals, fodders, woods, &c.

Analyses showed that Australian native grasses have a markedly lower phosphorus content than European; that acclimatised European grasses have a higher phosphorus content than native Australian, but lower than the same kinds of grasses grown in Europe; that the wood of the Australian trees has a lower phosphorus content than that of European trees, and also that the phosphorus content of Victorian wheat-flour is low.

Lastly, it was urged that as the yearly loss of phosphorus from Victorian grazing lands by export of their products is considerable, it is a matter of economic importance that such phosphorus should be restored.

4. *An Experimental Investigation on Concussion of the Spinal Cord and Allied Conditions.* *By* ALAN NEWTON, *M.S.*

In this investigation an attempt has been made to determine the effect upon the spinal cord of varying degrees of concussion and compression.

Methods.—The animals employed were dogs, cats, and monkeys. The momentum of a glass rod 8 mm. in diameter weighing 50 grammes falling upon the exposed cord, or upon the superficial surface of the laminæ of the upper lumbar vertebræ, caused the concussion. Motor and sensory conduction in the cord was tested at varying intervals after the production of the concussion. It was found that very slight injuries of the exposed cord produced marked alteration in the conduction, although the anatomical changes demonstrable in the cord after such injuries were very slight. Alteration of conduction in the spinal cord can be produced by a concussing force directed upon the superficial surface of the spinal column, although no macroscopic change in vertebral structure is produced. After the abolition of motor efferent conduction afferent conduction can still be demonstrated.

SYDNEY.

FRIDAY, AUGUST 21.

Demonstrations by Professor Sir T. P. ANDERSON STUART.

(*a*) The Functions of the Corpora Arantii.
(*b*) An Apparatus for illustrating the Nature of Sound Waves in Air.
(*c*) The Cyclograph, an Instrument for quickly marking Microscopical Slides.
(*d*) The Action of the Stapedius Muscle.
(*e*) The Effect of Simultaneous Contraction of the Intercostal Muscles.

The following Papers were then read :—

1. *Climate from the Physiological Point of View.* *By* Professor W. A. OSBORNE.

The theory of wet-bulb temperatures in their relation to body temperature we owe to Haldane. Harrington had already surmised their importance, and had mapped the United States with wet-bulb isotherms for the month of July. In estimating climatic conditions in Australia, in so far as they affect the body, the wet-bulb isotherms are extremely useful. There are, however, certain limitations in the use of this method. I have found that the wet bulb is not nearly so responsive to change in wind velocity as the human body. A typical instance of this is seen when a hot dry north wind in Victoria gives place to a cool southerly breeze with or without electrical disturbance and rain. The wind drops, the sky becomes overcast, and a feeling of oppression is experienced, whilst visible sweating may be more readily provoked. Owing to the overclouding the shade dry-bulb temperature has fallen, and in nearly every instance the wet bulb has fallen too. If, however, a wet-bulb thermometer is employed, the bulb of which is surrounded by a cage covered with some closely woven fabric, it is found to be much more sensitive to wind velocity than the naked wet-bulb thermometer. Such a thermometer, too, shows in a 'change' an increase in the height of the mercury column during the oppressive period before the cool breeze. These 'jacketed' wet-bulb thermometers I have made with a cylindrical cage of copper-gauze covered with fine-mesh bolting-cloth. Unfortunately the cloth soon becomes greased and clogged. Two or three ply of fine copper-gauze will act fairly well instead of the bolting-cloth, but here, too, the apertures become filled and readings lack constancy. I have been compelled to fall back on quite impervious material in the form of a hollow cylinder, open below, but having a perforated stopper of cork above, through which the thermometer stem passes. The bulb with its usual cotton covering is placed in the centre of the cylinder. In this instrument a considerable degree of sensitiveness to change of air velocity can be demonstrated. It will frequently show a rise at the onset of a thunderstorm when the ordinary wet bulb gives a fall.

2. *Forms of Precipitation of Inorganic Colloids.* *By* Professor B. MOORE, *F.R.S.*

3. *The Action of Ultra-violet Light on Solutions of Organic Substances.* *By* Professor B. MOORE, *F.R.S.*

4. *The Presence of Iron Salts in the Colourless Portion of the Chloroplast, and the Mechanism of Photo-Synthesis by Iron Salts.* *By* Professor B. MOORE, *F.R.S.*

5. *Note on the Deposit obtained from Milk by Spinning in a Centrifuge.* *By* H. S. HALCRO WARDLAW.

When milk is spun in a centrifuge a white deposit accumulates in the containing vessels. The first portion of this deposit consists of cellular material, the remainder is composed of minute granules, less than 0·001 mm. in diameter. The removal of this material from milk does not raise its freezing-point. The composition of this deposit is not constant, but the figures given below show its nature :—

100 parts of dry deposit contain—

Ash		8 parts
(P_2O_5	3·6)	
(CaO	3·7)	
Combustible Substance		92 „
(Caseinogen	57)	
(Lactose	19)	
(Remainder	16)	

The sixteen parts of combustible substance not accounted for contain 2·5 parts of nitrogen, and consist, in part at any rate, of protein coagulated by boiling.

A considerable portion of the deposit (up to 60 per cent.) is soluble in a volume of water equal to that of the milk from which it was removed, and the soluble portion contains the bulk of the ash (up to 90 per cent.).

The percentages of ash in the deposits obtained from the same sample of milk after various periods of spinning are not the same, but first increase and then decrease as the spinning is continued. With an initial percentage of ash of 7·0 the maximum percentage was reached after about two hours' spinning and amounted to 8·0.

The rate of accumulation of this deposit also varies with the time of spinning, but approximately inversely to the percentage of ash, first decreasing to a minimum, then increasing. The average rate of deposition under the conditions of the experiments was about 70 mg. per hour per 100 c.c. of milk. This subsequent increase in the rate of deposition is peculiar.

6. *Some Notes on the Symbiotic Activities of Coliform and other Organisms on Media containing Carbohydrates and Allied Substances.* *By* BURTON BRADLEY.

(1) Consideration of the effect of coliform aërogene organisms in company with coliform anaërogene-oxygene organisms on media containing a carbohydrate (or allied substance) not affected by the former organisms, and from which acid, without gas, is produced by the latter.

(2) Consideration of the effect of coliform aërogene organisms on the sterilised acid or sterilised neutralised products of the action of coliform anaërogene-oxygene organisms, other conditions being as in (1).

(3) Considerations of various factors concerned in the results produced.

(4) Consideration of the symbiotic activity of other organisms.

(5) General conclusions.

TUESDAY, AUGUST 25.

The following Papers were read :—

1. *Changes in the Reaction of Milk under Different Conditions. By* Professor T. H. Milroy, *M.D.*

The reaction of the milk was determined by estimating the hydrogen-ion concentration by the electrometric method. When hydrogen is passed through fresh milk the H concentration is lowered by a removal of carbonic acid. This may be avoided either by passing the milk into an electrode already charged with hydrogen and then shaking the milk in the vessel until it is saturated with the gas, or better by passing the hydrogen through a series of tubes containing milk before passing into the electrode containing the same milk. When this is done the H concentration of fresh milk is found to vary from about $1{\cdot}58 \times 10^{-7}$ N normal to $2{\cdot}24 \times 10^{-7}$ N. Greater acidities than the latter are due to commencing acid fermentation of the milk. When milk is heated for about an hour at a temperature a little below boiling-point, evaporation being prevented, the milk when cooled to room temperature shows a slightly higher H concentration than the same milk examined fresh. There is also a greater constancy in the concentration when one compares a large number of specimens. Such heated milk does not undergo coagulation with rennin unless its acidity is raised by the addition of weak acid or by the addition of calcium chloride. The addition of calcium chloride raises the H concentration and produces coagulability of the milk more readily, that is at a lower H concentration, than when weak acids have been added. When potassium oxalate is added to milk, in just sufficient quantity to prevent coagulation, the H concentration is lowered below the level of that observed in ordinary coagulable milk. If one now estimates the H concentration after the addition of just sufficient $CaCl_2$ to produce clotting, it is found to be within the H concentration limits of ordinary coagulable milk. The addition of oxalic acid to oxalate milk does not produce true coagulation.

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2. *Variations in the Hydrogen-Ion Concentrations of the Blood. By* Professor T. H. Milroy, *M.D.*

The concentration of the hydrogen-ions in the blood can be most satisfactorily determined by the electrometric method. There are certain difficulties entailed in the method as employed for blood, owing to the fact that the blood is rich in oxygen and in carbonic acid. The former gas leads to a depolarisation of the hydrogen plate, and so the estimation can only be made after complete reduction of the blood, while the latter gas must be prevented from leaving the blood, as the variations in the hydrogen-ion concentration are mainly due to changes in the carbonic acid content of the blood.

When the necessary precautions are taken to avoid these fallacies the method is sufficiently accurate to enable one to determine the variations due to alterations in respiration if these alterations be of a sufficiently marked character.

It may readily be shown that the concentration falls after a period of prolonged pulmonary ventilation and rises again during the period of apnœa. If the period of ventilation with air be succeeded by a short period with 10 per cent. carbonic acid in air, then the usual fall in concentration does not occur, and so there is no resultant apnœa.

The fall that is produced after ventilation with rich oxygen-holding mixtures is of the same degree as that observed after inflation with air. To show the degree of the changes in H concentration an example may be given.

Before ventilation the hydrogen-ion concentration of the blood was $\cdot 3715 \times 10^{-7}$ N, while after fifteen minutes' ventilation with air, followed by two minutes and fifteen seconds with oxygen, the concentration was $\cdot 1995 \times 10^{-7}$ N. An apnœic pause of three minutes ten seconds' duration followed the ventilation period, and at the close of this the concentration had risen to $\cdot 3548 \times 10^{-7}$ N. Ten minutes later when breathing was again of normal character the concentration had risen to $\cdot 3890 \times 10^{-7}$N.

In certain rare cases ventilation does not produce the usual fall, and when

this is the case no apnœic pause is to be observed. The probable reason for this departure from the normal is that, although the ventilation has produced a removal of carbonic acid from the blood, the fall in hydrogen-ion concentration is prevented by a formation of acid products of incomplete combustion.

3. *The Action of the Venom of some Australian Snakes on the Corpuscles of some Bloods. By* Professor D. A. Welsh, *M.D., and* Dr. H. G. Chapman.

4. *A Comparison of the Activity of Extracts of the* Pars Intermedia *and* Pars Nervosa *of the Ox Pituitary. By* Professor P. T. Herring, *M.D., F.R.C.P.E.*

It is possible to remove from the posterior lobe of the fresh ox pituitary with the aid of a fine pair of curved scissors small quantities of the epithelium of the *pars intermedia.* The material thus obtained from a number of pituitaries was dried, powdered in a mortar, and made up by boiling in Ringer's solution into extracts of definite percentages of the dried epithelium. *Pars nervosa* was similarly isolated and prepared.

The extracts were tested upon the virgin rat's uterus, the method employed being a modification of Kehrer's and Dale's procedures. The extracts were also tested upon the mammary secretion of lactating rats, and upon the blood-pressure, kidney volume, and secretion of urine in cats.

The extracts of both *pars intermedia* and *pars nervosa* exercise a powerful stimulating effect upon the uterus and the secretion of milk, but the *pars nervosa* gives the stronger action in each case. By a comparison of the action of different strengths of extracts it is found that the *pars nervosa* is from two to five times as powerful in its effects as *pars intermedia.* Very minute doses are active; immersion of the uterus for 15 sec. in ·0005 per cent. of the dried *pars nervosa* results in a well-marked contraction. The skate pituitary, in which there is no *pars nervosa,* also yields a material which acts on the uterus and mammary secretion in a similar manner. The pure *pars glandularis* of the anterior lobe of the ox pituitary has no such action. It is probable, therefore, that the active material has its origin in the epithelial cells of the *pars intermedia.* Many of these cells invade the *pars nervosa,* undergoing an alteration there into hyaline bodies, which are very numerous in the *pars nervosa* of the ox pituitary.

Extracts of the *pars intermedia* show no specific action upon the blood-pressure, kidney volume, and urinary secretion of cats, even in doses of a ·5 per cent. extract of the dried epithelium. Extracts of skate's pituitary are similarly inactive. Extracts of the *pars nervosa* on the other hand give marked effects even in very minute doses. The injection into the jugular vein of 2 c.c. of a ·01 per cent. extract of dried *pars nervosa* gives a typical prolonged rise of blood-pressure, great dilatation of the kidney, and increase of the secretion of urine. A similar dose of a ·001 per cent. extract shows a slight action of the same nature.

The evidence points to there being at least two separate active principles in the posterior lobe of the pituitary body. The one, derived from the *pars intermedia,* acts upon the uterus and mammary gland, the other, found only in the *pars nervosa,* brings about the rise of blood-pressure, and acts specifically upon the kidney dilating its blood-vessels, and causing increased secretion of urine.

The principle which acts specifically on the kidney may be derived from the ependyma cells of the *pars nervosa,* but this is unlikely. Extracts of no other part of the central nervous system, *e.g.,* the *filum terminale* of the spinal cord, have any such action. It is more likely that the material is derived in some manner from a further breaking down of the hyaline bodies, and has, therefore, its ultimate source also from the epithelial cells of the *pars intermedia.*

The expenses of this research have been borne by a grant from the Carnegie Trust.

5. *The Influence of the Thyroid upon the Activity of the Suprarenals and Pituitary Body. By* Professor P. T. Herring, *M.D., F.R.C.P.E.*

6. *On the Freezing-point of the Laked Red Blood Corpuscles of Man and some Domesticated Animals.* By Dr. H. G. Chapman.

If a mixture of blood and 0·9 per cent. NaCl be subjected to immediate microscopical examination the red corpuscles are seen to be crenated. When less concentrated solutions of salt are used, crenated corpuscles are numerous until the concentration of salt falls below 0·55 per cent. Laking of the corpuscles commences when the concentration of the salt falls below 0·65 per cent.

Measurements of the freezing-point of laked solutions of the red corpuscles, separated in the centrifuge, have been made by Beckmann's apparatus. These freezing-points have been invariably higher than those of the serum of the same sample of blood. When the corpuscles have been washed with salt solutions of different concentrations, the freezing-points of the solutions of the laked corpuscles have risen after each washing. After three washings with an equal amount of salt solution, the freezing-points of the solutions of the washed corpuscles have risen about 0·2° C. When, however, the red corpuscles are washed with salt solution saturated with tri-basic calcium phosphate, the freezing-points of the solutions of red corpuscles remain constant after each washing.

The concentration of the contents of the corpuscles is diminished by washing with salt solution, but not by washing with salt solution saturated with calcium phosphate.

7. *Precipitin Reactions in Pathological Human Urines.* By Cyril Shellshear.

Demonstration of precipitin reactions to human serum :—

(*a*) Albuminous urine	1.	Containing	high	percentage albumin.
	2.	,,	low	,, ,,
(*b*) Eclamptic urine	1.	,,	high	,, ,,
	2.	,,	low	,, ,,

8. *A Contribution to the Psychology of Written Errors.* By Dr. H. Tasman Lovell.

9. *Analysis of Conation.* By Dr. H. Tasman Lovell.

10. *The Relation of the Feeling of Familiarity to Belief.* By Dr. H. Muscio.

11. *Mind and Matter.* By Dr. Law.

Section K.—BOTANY.

President of the Section.—Professor F. O. Bower, D.Sc., F.R.S.

The President delivered the following Address at Sydney, on Friday, August 21:—

To preside over the Botanical Section on the occasion of its first Meeting in Australia is no slight honour, though it also imposes no small responsibility. We Members from Great Britain have a deep sense of the advantage which we derive from visiting these distant shores. I am doubtful whether any scientific profit we can confer by our coming here can balance that which we receive; while over and above this is the personal kindliness of the Australian welcome, which on behalf of the visitors of this Section from the Old Country I take this opportunity of gratefully acknowledging. Of the Members of the British Association, those who pursue the Natural Sciences may expect to gain most by their experiences here; and perhaps it is the Botanists who stand to come off best of all. Living as most of us do in a country of old cultivation, the vegetation of which has been controlled, transformed, and from the natural floristic point of view almost ruined by the hand of man, it is with delight and expectation that we visit a land not yet spoilt. To those who study Ecology, that branch of the science which regards vegetation collectively as the natural resultant of its external circumstances, the antithesis will come home with special strength, and the opportunity now before them of seeing Nature in her pristine state will not, I am sure, be thrown away.

I may be allowed here to express to the Australian Members of the Section my regret that the Presidency for this occasion should not have fallen to one who could with unusual weight and knowledge have addressed them from the floristic and geographical point of view. I mean, to Professor Bayley Balfour, of Edinburgh, who was actually invited by the Council to preside. He could have handled the subject of your rich and peculiar Flora with detailed knowledge; and, with the true Hookerian touch, he would have pictured to you in bold outlines its relation to present problems. Failing such equipment, I may at least claim to have made some of your rare and peculiar forms the subject of special study at intervals spread over thirty years: for it was in 1884 that I was supplied with living plants of *Phylloglossum* by Baron Ferdinand von Müller, while a paper to be published this year contains details of a number of Ferns kindly sent to me by various collectors from New Zealand. I have been personally interested more especially in your rare Pteridophytes, isolated survivals as they surely are of very ancient vegetation. I propose to indicate later in this Address some points of interest which they present. But first I shall offer some more general remarks on the history of the investigation of the Australian Flora, as a reminder of the recent death of Sir Joseph Hooker, whose work helped so greatly to promote a philosophical knowledge of the Flora of this quarter of the globe.

Few, if any, of the large areas of the Earth's surface have developed their coat of vegetation under such interesting conditions as that which bears the Australasian Flora. In its comparative isolation, and in its freedom from the disturbing influence of man, it may be held as unique. We may picture to ourselves the field as having been open to evolutionary tendencies, unusually free

from the incursion of competitive foreign types, and with its Flora shaped and determined through long ages in the main by climatic influences. Naturally the controlling effect of animal life had been present throughout, as well as that of parasitic and fungal attack; but that potent artificial influence, the hand of man, was less effective here than in almost any other area. The aborigines were not tillers of the soil: in their digging for roots and such-like actions they might rank with the herbivorous animals, so far as they affected the vegetation. Probably the most powerful influence they exercised was through fire. And so the conditions remained, the native Flora being practically untouched, till the visit of Captain Cook in 1770: for little account need be taken of the handful of specimens collected by Dampier in the seventeenth century.

Captain Cook shipped with him in the *Endeavour* a very remarkable man, viz., Joseph Banks, whom Dr. Maiden has described as 'the Father of Australia.' He not only acted as the scientific director of the expedition, but he was also its financier. Educated at Eton and Oxford, he found himself as a young man possessed of an ample fortune. Though devoted to field sports, he did not, like so many others, spend his life upon them. Following the dictates of a taste early awakened in him, he turned his attention to travel for scientific ends. His opportunity came when Cook was fitting out the *Endeavour* for his first voyage to the Southern Seas. Banks asked leave of the Admiralty to join the expedition, which was granted, and he furnished all the scientific stores and a staff of nine persons at his own expense.

The story of that great expedition of 1768 to 1771 is given in 'Cook's Voyages,' compiled by Dr. Hawkesworth, a book that may be found in every library. Though it is evident throughout that Banks took a leading part in the observational work of the expedition, it has not been generally known how deeply indebted Hawkesworth was to Banks for the scientific content of his story. This became apparent only on the publication of Banks' own Journal 125 years after the completion of the voyage. The circumstances of this have a local interest, so I may be excused for briefly relating them.

Banks' papers, including the MS. Journal, passed with his library and Herbarium on his death to his librarian, Robert Brown. On the death of the latter they remained in the British Museum. But after lying there for a long period they were claimed and removed by a member of Banks' family, and were put up for auction. The Journal was sold for 7*l.* 2*s.* 6*d.*, and the last that has been heard of it is that it came into the possession of a gentleman in Sydney. Perhaps it may be lying within a short distance of the spot where we are now met. This valuable record, fit to rank with Darwin's 'Voyage of the *Beagle*,' or Moseley's account of the 'Voyage of the *Challenger*,' might thus have been wholly lost to the public had it not been for the care of Dawson-Turner, who had the original transcribed by his daughters, helped by his grandson, Joseph Dalton Hooker. The boy was fascinated by it, and doubtless it helped to stimulate to like enterprises that botanist to whom Australia owes so much. The copy thus made remained in the British Museum. Finally, from it in 1896 Sir Joseph Hooker himself edited the Journal, in a slightly abridged form. It is now apparent how very large a share Banks actually took in the observation and recording, and how deeply indebted to him was the compiler of the account of the voyage published more than a century earlier, not only for facts, but even for lengthy excerpts.

The plants collected in Australia by this expedition amounted to some 1,000 species, and with Banks' Herbarium they found, after his death, a home in the British Museum. Several minor collections were subsequently made in Australia, but the next expedition of prime importance was that of Flinders in 1801 to 1805. What made it botanically notable was the presence of Robert Brown. Hooker speaks of this voyage as being, 'as far as Botany is concerned, the most important in its results ever taken.' The collections came from areas so widely apart as King George's Sound, Southern Tasmania, and the Gulf of Carpentaria. These, together with Banks' plants and other minor collections, formed the foundation for Brown's 'Prodromus Floræ Novæ Hollandiæ,' a work which was described in 1860 by Sir Joseph Hooker as being 'though a fragment . . . the greatest botanical work that has ever appeared.' It was published in 1810. I must pass over without detailed remark the notable pioneer work of Allan Cunningham, and of some others. The next outstanding fact in the history of

Australian Botany was the voyage of Ross, with the *Erebus* and the *Terror*; for with him was Joseph Hooker, whose botanical work gave an added distinction to an otherwise remarkable expedition.

The prime object of the voyage was a magnetic survey, and this determined its course. But in the intervals of sailing the Antarctic Seas the two ships visited Ascension Island, St. Helena, the Cape, New Zealand, Australia, Tasmania, Kerguelen Island, Tierra del Fuego, and the Falkland Islands. Thus Hooker had the opportunity of collecting and observing upon all the great circumpolar areas of the Southern Hemisphere. He welded together the results into his great work 'The Antarctic Flora.' It was published in six large quarto volumes. In them about 3,000 species are described, while on 530 plates 1,095 species are depicted, usually with detailed analytical drawings. But these magnificent volumes did not merely contain reports of explorations, or descriptions of the many new species collected. There was much more than this in them. All the known facts that could be gathered were incorporated, so that they became systematically elaborated and complete Floras of the several countries. Moreover, in the last of them, the 'Flora Tasmaniæ,' there is an Introductory Essay, in which the Australasian Flora was for the first time treated as a whole, and its probable origin and its relation to other Floras discussed. Further, questions of the mutability and origin of species were also raised in it. The air was full of such questions in 1859; the essay was completed in November of that year, less than twelve months after the joint communications of Darwin and Wallace had been made to the Linnean Society, and before the 'Origin of Species' was published. It was to this essay that Darwin referred when he wrote that 'Hooker has come round, and will publish his belief soon.' But this publication of his belief in the mutability of species was not merely an echo of assent to Darwin's own opinion. It was a reasoned statement, advanced upon the basis of his 'own self-thought,' and his own wide systematic and geographical experience. From these sources he drew support for 'the hypothesis that species are derivative and mutable.' He points out how the natural history of Australia seemed specially suited to test such a theory, on account of the comparative uniformity of the physical features being accompanied by a great variety in its Flora, and the peculiarity of both its Fauna and Flora, as compared with other countries. After the test had been made on the basis of the study of some 8,000 species of plants, their characters, their spread, and their relations to those of other lands, Hooker concluded decisively in favour of mutability, and a doctrine of progression. After reading this essay, Darwin wrote that it was to his judgment 'by far the grandest and most interesting essay on subjects of the nature discussed I have ever read.'

But beyond its historical interest in relation to the 'Origin of Species,' Hooker's essay contained what was up to its time the most scientific treatment of a large area from the point of view of the Plant-Geographer. He found that the Antarctic, like the Arctic Flora, is very uniform round the Globe. The same species in many cases occur on every island, though thousands of miles of ocean may intervene. Many of these species reappear in the mountains of Southern Chili, Australia, Tasmania, and New Zealand. The Southern Temperate Floras, on the other hand, of South America, South Africa, Australia, and New Zealand differ more among themselves than do the Floras of Europe, Northern Asia, and North America. To explain these facts Hooker suggested the probable former existence, during a warmer period than the present, of a centre of creation of new species in the Southern Ocean, in the form of either a continent or an archipelago, from which the Antarctic Flora radiated. From the zoological side a similar difficulty arises, and the hypothesis of a land-connection has been widely upheld, and that it existed as late as Mid-Tertiary times. The theory took a more definite form in the hands of Osborn (1900), who pictured relatively narrow strips of land connecting respectively South America on the one side and Tasmania and New Zealand on the other with the existing Antarctic land-area. This would accord well enough with the suggestion of Lowthian Green, that the plan of land-elevations on the Earth is approximately tetrahedral; and it is, I believe, in line with the views of those who are best informed on Antarctic Geography and Geology, as studied from the land itself. It may be hoped that further Antarctic discovery may bring fresh facts to bear upon this question, for it is to the positive data acquired from

study of the Earth's crust that we must look, rather than to the exigencies of botanists and zoologists, for its final solution.

But the hypothesis of an Antarctic Land-Connection has been held open to doubt in various quarters. As Sir Wm. Thiselton Dyer has recently pointed out, Darwin himself dissented, though regretfully, from the sinking of imaginary continents in a quite reckless manner, and from the construction of land-bridges in every convenient direction. From the geological side Dana laid down the positive proposition that the Continents and Oceans had their general outline and form defined in earliest time. Sir John Murray, whose recent death we so deeply deplore, was an undeniable authority as to the Ocean-floor. He wrote quite recently with regard to Gondwana-land, that 'the study of Ocean-depths and Ocean-deposits does not seem in any way to support the view that continental land has disappeared beneath the floor of the Ocean in the manner indicated.' He suggested that the present distribution of organisms is better interpreted by the North Polar theory of origin. The 'continuous current of vegetation' southward at the present time was recognised by Hooker himself, and definite streams of northern forms have been traced by him extending even to Australia and Tasmania. This might account for much in present-day distribution; though it seems doubtful whether it would fully explain the extraordinary distribution of Antarctic Plants. The problem must for the present remain an open one.

This whole question, however, has a connection with the still wider difficulty of the existence within the Polar area of ancient Floras. In the north the fossils are even of sub-tropical character. Coal has been found in lands with a five months' night. How did such plants fare if the seasonal conditions were at all like the present? To explain this it would be a physiological necessity to assume either an entirely different climatal condition in those regions from that of the present time; or, as has been suggested, some shifting or creeping of the Earth's crust itself. These are, however, questions which we cannot undertake to discuss with effect in the Botanical Section. We must not do more than recognise that an unsolved difficulty exists.

We pass now from Hooker's great work to the last of the classical series, viz., the 'Flora Australiensis' of Bentham and Baron Ferdinand von Müller. It is embodied in seven volumes, and was completed in 1878. Bentham, while assenting in his 'concluding preface' to the principles laid down by Hooker in the Tasmanian Flora, recognised as the chief component part of the present Flora of Australia the indigenous genera and species, originated or differentiated in Australia, which never spread far out of it. Secondly, an Indo-Australian Flora showing an ancient connection between Australia and the lands lying to the north. It is represented especially in tropical and sub-tropical East Queensland. Then there is the Mountain Flora common to New Zealand, and extending generally to the southern extra-tropical and mountain regions, while other constituents are ubiquitous maritime plants, and those which have been introduced since the European colonisation. But the most remarkable, as they are the least easily explained, are some few plants identical with species from North and West America, and from the Mediterranean. They are stated to be chiefly annuals, or herbaceous or shrubby plants; free-seeders; while their seeds long retain the power of germination. This may perhaps give the clue to this curious conundrum of distribution.

It has been fortunate that the duty of working out this remarkable Flora should have fallen into the hands of such masters as Robert Brown, Sir Joseph Hooker, and Bentham. The foundations were thus surely laid. The further progress of knowledge has been carried on by the late Baron Ferdinand von Müller, and it may be confidently left in the hands of others who are still with us. The completion of the task of observing and recording may still be far ahead. But I may be pardoned if I utter a word of anticipatory warning. There is at the present time a risk that the mere work of tabulating and defining the species in a given country may be regarded as the only duty of a Government Botanist; that, whenever this is completed, his occupation will be gone. Some such erroneous idea, together with a short-sighted economy, is the probable explanation of the fact that certain positions hitherto held by professional botanists have recently been converted into positions to be held by agriculturists. In the countries where this has happened (and I refer to no part of Australasia) the vegetation had been very adequately, though not yet exhaustively, worked, as

regards the Flowering Plants and Ferns. But who that knows anything about plants would imagine that the ascription to a genus or order, or the designation by a couple of Latin names with a brief specific description, exhausts what it is important to know about a species? In most cases it is after this has been done that the real importance of its study begins. Such possibilities as these do not appear to have been appreciated by those who advised or controlled these official changes. I have no desire to undervalue the agriculturist or the important work which he does. But he is engaged in the special application of various pure sciences, rather than in pure science itself. Advance in the prosperity of any country which has progressed beyond the initial stages of settlement follows on the advance of such knowledge as the devotee of Pure Science not only creates, but is also able to inculcate in his pupils. It is then imperative that, in any state which actively progresses, provision shall be made for the pursuit of pure as well as of applied science. In my view an essential mistake has been made in changing the character of the appointments in question from that of botanists to that of agriculturists. For the change marks the abandonment of Pure Science in favour of its specialised and local application.

The head of such an institution should always be a representative of Pure Science, thoroughly versed in the nascent developments of his subject. He could then delegate to specialists the work of following out into detail such various lines of special application as Agriculture, Acclimatisation, Plant-Breeding, Forestry, or Economics. Or, if the organisation were a large one, as we may anticipate that it would become in the Capital of a great State, separate Institutes might develop to serve the several applied branches, while to a central Institute, in touch with them all, might be reserved the duty of advancing the Pure Science from which all should draw assistance and inspiration.

It matters little how this principle works out in detail, if only the principle itself be accepted, viz., that Pure Science is the fount from which the practical applications spring. Sydney, as the Capital of a great State, has already laid her course, as regards Botanical Science, in accordance with it. Her Botanic Garden and the recently developed Botanical Department in the University (which, I understand, may find its home ultimately in the Botanic Garden) will serve as centres of study of the Pure Science of Botany. This will readily find its application to Agriculture, to Forestry, to Economics, and in various other lines present and future. I am convinced that it is in the best interest of any State that can possibly afford to do so to encourage and liberally endow the central establishment where the Pure Science of Botany is pursued, and to continue that encouragement and endowment, even though results of immediate practical use do not appear to be flowing from it at any given moment. For in these matters it is impossible to forecast what will and what will not be eventually of practical use. And in any case as educational centres the purely botanical establishments will always retain their important function of supplying that exact instruction, without which none can pursue with full effect a calling in the applied branches.

We may now turn from generalities to certain special points of interest in your peculiar Flora which happen to have engaged my personal attention. They centre round a few rare and isolated plants belonging to the Pteridophyta, a division of the Vegetable Kingdom which there is every reason to believe to have appeared relatively early in the history of Evolution. But though the type may be an ancient one, it does not follow that every representative of it preserves the pristine features intact. Throughout the ages members of these early families may themselves have progressed. And so among them to-day we may expect to find some which preserve the ancient characters more fully than others. The former have stood still, and may be found to compare with curious exactitude with fossils even of very early date. The latter have advanced, and though still belonging to the ancient family, are by their modifications become essentially modern representatives of it. For instance, the Fern *Angiopteris* has a sorus which very exactly matches sori from the Palæozoic period, and it may accordingly be held to be a very ancient type of Fern. On the other hand, the genera *Asplenium*, or *Polypodium*, include Ferns of a type which has not been recognised from early fossil-bearing rocks, and they may be held to be essentially modern. But still all of them clearly belong to the family of the Ferns.

In the Australian Flora only three of the four divisions of the Pteridophyta

are represented. For, curiously enough, there does not appear to be any species on your Continent of the widely spread genus Equisetum, the only living genus of that great phylum of the Equisetales, which figured so largely in the Palæozoic Period; and this notwithstanding that one species (*E. debile*) is present among the Polynesian Islands. But all the three other divisions of the Pteridophyta are included, and are represented in each case by plants which show peculiar and probably for the most part archaic characters. I propose to sketch before you very briefly the points of interest which the more notable of these archaic types present. Some justification may be found for my doing so because nearly all of them have been submitted to detailed study in my laboratory in Glasgow, and much of the work has been done upon material supplied to me by your own Botanists. I take this opportunity of offering to them collectively my hearty thanks.

The tenure by Dr. Treub of the office of Director of the Botanic Gardens of Buitenzorg was rendered famous by his personal investigations, and chiefly by his classical researches on the Lycopods. These were followed up by other workers, and notably by Bruchmann; so that we now possess a reasonable basis for comparison of the different types of the family as regards the prothallus and embryology, as well as of the sporophyte plant; and all these characters must be brought together as a basis for a sound conclusion as to their phyletic seriation. The most peculiar living Lycopods are certainly *Isoëtes* and *Phylloglossum*, both of which are found in Australia. The former need not be specially discussed here, as it is a practically world-wide genus. It must suffice to say that it is probably the nearest living thing to the fossils *Lepidodendron* and *Sigillaria*, and may be described as consisting of an abbreviated and partially differentiated *Lepidostrobus* seated upon a contracted stigmarian base.

But *Phylloglossum*, which is peculiar to the Australasian region, naturally claims special attention. The plant is well known to botanists as regards its external features, its annual storage tuber, its leafy shoot with protophylls and roots, and its simple shaft bearing the short strobilus of characteristic Lycopod type. But its prothallus has never been properly delineated, though it was verbally described by Dr. A. P. W. Thomas in 1901 (Proc. Roy. Soc., vol. 69, p. 285). Perhaps the completed statement may have been reserved as a pleasant surprise for this Meeting. But the description of thirteen years ago clearly shows its similarity to the type of *Lycopodium cernuum*. The sporophyte compares rather with *L. inundatum*. Both of these are species which, though probably not the most primitive of the genus, are far from being the most advanced. As all botanists know, the question of the position of *Phylloglossum* chiefly turns upon the view we take of the annual tuber and its protophylls. Treub, finding similar conditions in certain embryos of Lycopods, called it a 'protocorm,' and believed that he recognised in it an organ of archaic nature, which had played an important part in the early establishment of the sporophyte in the soil, physiologically independent of the prothallus. I must not trouble you here with the whole argument in regard to this view. Facts which profoundly affect the conclusion are those showing the inconstancy of occurrence of the organ. Mr. Holloway has recently described it as of unusual size in your native *L. laterale*, as it is also in *L. cernuum*. But it is virtually absent in those species which have a large intraprothallial foot, such as *L. clavatum*, as well as in the genus *Selaginella* and in *Isoëtes*. In *L. Selago*, which on other grounds appears to be primitive, there is no 'protocorm.' Such facts appear to me to indicate caution. They suggest that the 'protocorm' is an opportunist local swelling of inconstant occurrence, which, though biologically important in some cases, is not really primitive.

If this is the comparative conclusion, then our view will be that *Phylloglossum* is a type of Lycopod which has assumed, perhaps relatively recently, a very practical mode of annual growth. Related, as it appears to be on other points, with the *L. inundatum* group of species, it has bettered their mode of life. *L. inundatum* dies off each year to the very tip of its shoot, so that only the bud remains to the following season. It is notable that Goebel has described long ago how the young adventitious buds of this species start with small 'protocorms,' quite like those of *Phylloglossum* itself, or like the embryo of *L. cernuum*. And so we may conclude that in *Phylloglossum* a tuberous development, containing a store to start the plant in the spring, has been added to what

is already seen normally each year in *L. inundatum*. And this mode of life of *Phylloglossum* begins, as Thomas has shown, with its embryo. This appears to me to be a rational explanation of the 'protocorm' of *Phylloglossum*; but it robs the plant of much of its theoretical interest as an archaic form

The phylum of the Sphenophyllales was originally based on certain slender straggling plants of the genus *Sphenophyllum* found in the Palæozoic Rocks; but they apparently died out in the Permian Period. Your native genera *Tmesipteris* and *Psilotum* were ranked by earlier botanists with the Lycopods, but a better acquaintance with their details, and especially the examination of numerous specimens on the spot, indicated a nearer affinity for them with the Sphenophyllales. It was Professor Thomas who in 1902 first suggested that the Psilotaceæ might be included with the Sphenophyllæ in the phylum of the Sphenophyllales, and I personally agree with him. Dr. Scott, however, dissents, on the ground that the leaves are persistently whorled in the sphenophylls, while they are alternate in the Psilotaceæ; and while the former branch monopodially the latter dichotomise. But since both of these characters are seen to be variable within the not far distant genus *Lycopodium*, the differences do not seem to me to be a sufficient ground for keeping them apart as the separate phyla of Sphenophyllales and Psilotales. Whatever degree of actual relation we trace, such plants as *Tmesipteris* and *Psilotum* are certainly the nearest living representatives of the Sphenophylleæ, a fact which gives them a special distinction. The Psilotaceæ also stand alone in the fact that they are the only family of the Pteridophytes in which the gametophyte is still unknown. They produce spores freely, but there the story stops. Any young Australian who hits upon the way to induce these recalcitrant spores to germinate, and to produce prothalli and embryos, or who found their prothalli and embryos in the open, would have before him a piece of work as sensational as anything that could be suggested. Further, I am told that *Tmesipteris* grows here on the matted stumps of *Todea barbara*. I shall be alluding shortly to the fossil Osmundaceæ. May we not venture to fancy the possibility of some fossil *Osmunda* being found which has embalmed for us among its roots a Mesozoic or even a Tertiary Sphenophyll? And thus a link might be found between the Palæozoic types and the modern Psilotaceæ, not only in time, but even in character.

We pass now to the last phylum of the Pteridophyta, the Filicales. I am bound to say that for me its interest far outweighs that of the others, and for this reason. That it is represented by far the largest number of genera and species at the present day, while there is a sufficiently continuous and rich succession of fossil forms to serve as an efficient check upon our comparative conclusions.

Since 1890 it has been generally accepted that the Eusporangiate Ferns (those with more bulky sporangia) were phyletically the more primitive types, and the Leptosporangiate (those with more delicate sporangia) the derivative, and in point of time later. The fossil evidence clearly upholds this conclusion. But, further, it has been shown that the character of the sporangium is merely an indicator of the general constitution of the plants in question. Where it is large and complex, as in the Eusporangiates, all the apical segmentations are, as a rule, complex, and the construction of the whole plant relatively bulky. Where the sporangium is delicate and relatively simple all the apical segmentations follow suit, and the construction of the plant is on a less bulky model. On this basis we may range the Ferns roughly as a sequence, starting from relatively bulky types of the distant past, and progressing to the more delicate types of the present day. The large majority of the living species belong naturally to the latter. But the former are still represented by a few genera and species which, like other survivals from a distant past, are frequently of very restricted distribution.

An interesting feature of the Australasian Flora is that a considerable number of these relatively ancient forms are included in it. Thus the Marattiaceæ are represented by one species of *Marattia* and one of *Angiopteris*. Though in themselves interesting, they will be passed over without special remark, as they are very widely spread tropical forms.

All the three genera of Ophioglossaceæ are included, there being two species of *Ophioglossum* and two of *Botrychium*, while *Helminthostachys* is recorded

from Rockingham Bay. This Family is coming more than ever to the front in our comparisons, owing to their similarity in various aspects to the ancient Botryopterideæ. Though the Ophioglossaceæ have no secure or consecutive fossil history, still they may now be accepted as being very primitive but curiously specialised Ferns. Perhaps the most interesting point recently detected in them is the suspensor found by Dr. Lyon in *Botrychium obliquum*, and by Dr. Lang in *Helminthostachys*. This provides a point for their comparison with the similar embryonic condition in *Danæa*, as demonstrated by Professor Campbell. The existence of a filamentous initial stage of the embryo is thus shown for three of the most primitive of living Ferns. Its existence in all of the Bryophytes, and in most of the Lycopods, as well as in the Seed-Plants, is a very significant fact. Dr. Lang suggests that 'the suspensor represents the last trace of the filamentous juvenile stage in the development of the plant, and may have persisted in the Seed-Plants from their filicineous ancestry.' Such a possibility would fit singularly well with the theory of encapsulation of the sporophyte in the venter of the archegonium.

The representation of the ancient family of the Osmundaceæ in the Australasian Flora is very fine, though limited to five living species, while *Osmunda* itself is absent. It is, however, interesting that the family dates back locally to early fossil times. It was upon two specimens of *Osmundites* from the Jurassic Rocks in the Otago district of New Zealand that the series of remarkable papers on 'The Fossil Osmundaceæ' by Kidston and Gwynne-Vaughan was initiated. It is no exaggeration to say that these papers have done more than any other recent researches to promote a true understanding not only of the Osmundaceæ themselves, but of Fern-Anatomy as a whole. They have placed the stelar theory in Ferns for the first time upon a basis of comparison, checked by reference to stratigraphical sequence. It would be leading us too far for me to attempt here to summarise the important results which have sprung from the study of those fossils, so generously placed by Mr. Dunlop in the hands of those exceptionally able to turn them to account. It must suffice to say that it is now possible to trace as a fairly continuous story the steps leading from the protostelic state to the complex condition of the modern *Osmunda*. These facts and conclusions are to be put in relation with the anatomical data fast accumulating from the Ophioglossaceæ in the hands of Professor Lang and others. From such comparisons a rational explanation of the evolutionary steps leading to the complex stelar state in Ferns at large begins to emerge. This is no mere tissue of surmises, for the conclusions are based on detailed comparison of types occurring in lower horizons with those of the present day.

I must pass over with merely nominal mention your interesting representation of the ancient families of Schizæaceæ, Gleicheniaceæ, and Hymenophyllaceæ, all of which touch the very foundations of any phyletic system of Ferns. Also the magnificent array of Dicksonieæ and Cyatheæ, and of the important genus *Lindsaya*—Ferns which take a rather higher position in point of view of descent. But I am bound to devote a few moments to one of your most remarkable Ferns, endemic in New Zealand—the monotypic *Loxsoma*.

This species has peculiar characters which justify its being regarded systematically as the sole representative of a distinct Tribe. It is also restricted geographically to the North Island of New Zealand. These facts at once suggest that it is an ancient survival, a conclusion with which its solenostelic axis, its sorus and sporangium, and its prothallus readily accord. I have lately shown that the Leptosporangiate Ferns fall into two distinct Series, those in which the origin of the sorus is constantly superficial, and those in which it is as constantly marginal. *Loxsoma* is one of the 'Marginales.' It shares this position with the Schizæaceæ, Thyrsopterideæ, Hymenophyllaceæ, and Dicksonieæ, and the derivatives Davallieæ and Oleandreæ. Its nearest living relative is probably *Thyrsopteris*, which is again a monotypic species endemic in the Island of Juan Fernandez. There is also a probable relation to the genus *Loxsomopsis*, represented by one species from Costa Rica, and a second lately discovered in Bolivia. Such a wide and isolated distribution of types, which by their characters are certainly archaic, suggests that we see in them the relics of a Filicineous state once widely spread, which probably sprang from a Schizæaceous source, and with them represent the forerunners of the whole Marginal Series. If we look for further enlightenment from the fossils, it is to the Secondary Rocks that we

should turn. It is then specially interesting that Mr. Hamshaw Thomas has lately described a new Jurassic Fern, *Stachypteris Halli*, which has marginal sori, and is probably referable to a position like that of *Loxsoma* and *Thyrsopteris*, between the Schizæaceæ and the Dicksonieæ. In fact the gaps in the evolutionary series of the Marginales are filling up. We may await with confidence fresh evidence from the Jurassic Period, upon which Professor Seward is directing an intensive interest.

I should be ungrateful indeed if I did not mention your very full representation of Blechnoid Ferns: for developmental material of several of these has been sent to me by Dr. Cockayne, and others from New Zealand. A wide comparative study of the genus has led me to somewhat unexpected results in regard to the plasticity of the sorus, its phyletic fusions and disruptions. The consequent derivative forms are seen in *Woodwardia* and *Doodya* on the one hand, and on the other in *Scolopendrium* and *Asplenium*. These Ferns together constitute a coherent phylum springing ultimately from a Cyatheoid source. The details upon which this conclusion is based I hope to describe in a separate communication to the Section.

And lastly, the Hydropterideæ deserve brief mention. Represented in your Flora by two species of *Azolla*, and one each of *Marsilea* and *Pilularia*, they typify a condition which must theoretically have existed among Ferns in very early times, viz., the heterosporous state. But hitherto, notwithstanding the existence of our living Hydropterideæ, no fossil Fern with microscopic structure preserved had been detected from the Primary Rocks, showing this intermediate condition between the homosporous type and that of the Pteridosperms. This unsatisfactory position has now been resolved by Professor Lignier, who has recently described, under the name of *Mittagia*, a fossil from the Lower Westphalian, which bore sori of which the sporangia contained four megaspores, while the outer tissues of the sporangia resembled those of *Lagenostoma*. Pending the discovery of further specimens, these observations may be welcomed as filling with all probability a conspicuous gap in the evolutionary sequence of known forms.

From the rapid survey which I have been able to give you of some of the more notable Australasian Ferns of relatively archaic type, it is clear that they have a very interesting and direct bearing upon the phylesis of Ferns. The basis upon which conclusions as to phyletic sequence are arrived at is at root that of the Natural System of Classification generally—the recognition not of one character, or of two, but of as many as possible, which shall collectively serve as criteria of comparison. In the case of the Filicales we may use the characters of :—

(i) External form.
(ii) Constitution, as shown by simple or complex segmentation.
(iii) Dermal appendages, hairs or scales.
(iv) Stelar structure, simple or complex.
(v) Leaf-trace, coherent or divided.
(vi) Soral position.
(vii) Soral construction.
(viii) Indusial protections.
(ix) Sporangial structure, and mechanism of dehiscence.
(x) Spore-output.
(xi) Spore-form, and character of wall.
(xii) Form of prothallus.
(xiii) Position of the sexual organs, sunken or superficial
(xiv) Number of spermatocytes, and method of dehiscence.
(xv) Embryology.

In respect of all these criteria progressions of character may be traced as illustrated by known Ferns, and probably other criteria may emerge as study progresses. In each case, upon a footing of general comparison, checked as opportunity offers by reference to the stratigraphical sequence of the fossils, it may be possible to distinguish with some degree of certainty what is relatively primitive from what is relatively advanced. Thus, the protostele is generally admitted to be more primitive than the dictyostele, the simple hair than the flattened scale, and a high spore-output than a low one.

Applying the conclusions thus arrived at in respect of the several criteria, it

becomes possible upon the sum of them to lay out the species and genera of Ferns themselves in series, from the primitive to the advanced. In proportion as the progressions on the basis of the several criteria run parallel, we derive increased assurance of the rectitude of the phyletic sequences thus traced, which may finally be clinched, as opportunity offers, by reference to the stratigraphical occurrence of the corresponding fossils. This is in brief the phyletic method, as it may be applied to Ferns. It may with suitable variation be applied to any large group of organisms, though it is seldom that the opportunities for such observation and argument are in any sense commensurate with the requirements. Perhaps there is no group of plants in which the opportunities are at the moment so great as in the Filicales, and they are yielding highly probable results from its application.

The greatest obstacle to success is found in the prevalence of parallel development in phyla which are believed to have been of distinct origin. This is exemplified very freely in the Ferns, and the systematist has frequently been taken in by the resemblances which result from it. He has grouped the plants which show certain common characters together as members of a single genus. Sir William Hooker in doing this merged many genera of earlier writers. His avowed object was not so much to secure natural affinity in his system as readiness of identification: and consequently in the 'Synopsis Filicum' there are nominal genera which are not genera in the phyletic sense at all. For instance, *Polypodium* and *Acrostichum*, as there defined, may be held from a phyletic point of view to be collective groupings of all such Ferns as have attained a certain state of development of their sorus; and that they are not true genera in the sense of being associated by any kinship of descent: this is shown by the collective characters of the plants as a whole. Already at least four different phyletic sources of the Acrostichoid condition have been recognised, and probably the sources of the Polypodioid condition are no fewer. Such 'genera' represent the results of a phyletic drift, which may have affected similarly a plurality of lines of descent. It will be the province of the systematist who aims at a true grouping according to descent to comb out these aggregations of species into their true relationships. This is to be done by the use of wider, and it may be quite new, criteria of comparison. Advances are being made in this direction, but we are only as yet at the beginning of the construction of a true phyletic grouping of the Filicales. The more primitive lines are becoming clearer: but the difficulty will be greatest with the distal branches of the tree. For these represent essentially the modern forms, they comprise the largest number of apparently similar species, and in them parallel development has been most prevalent.

If this difficulty be found in such a group as the Filicales, in which the earlier steps are so clearly indicated by the related fossils, what are we to say for the Angiosperms? Our knowledge of their fossil progenitors is very fragmentary. But they are represented now by a multitude of forms, showing in most of their features an irritating sameness. For instance, vascular anatomy, that great resource of phyletic study in the more primitive types, has sunk in the Angiosperms to something like a dead level of uniformity. There is little variety found in the contents of embryo-sacs, in the details of fertilisation, or in embryology. Even the ontogeny as shown in the seedling stages affords little consolation to the seeker after recapitulation. On the other hand, within what are clearly natural circles of affinity there is evidence of an extraordinary readiness of adaptability in form and structure. Such conditions suggest that we see on the one hand the far-reaching results of parallel development, and on the other the effects of great plasticity at the present day, or in relatively recent times. Both of these are points which prevent the ready tracing of phyletic lines. In the absence of reliable suggestions from palæontology, the natural consequence is the current state of uncertainty as to the phyletic relations of the Angiosperms.

Various attempts have been or are being made to meet the difficulty. Some, on the basis of the recent observations of Wieland and others, are attempting along more or less definite monophyletic lines to construct, rather by forcible deduction than by any scientific method of induction, an evolutionary story of the Angiosperms. I do not anticipate that any great measure of success, beyond what is shown in a very polysyllabic terminology, and an appearance of knowing more than the facts can quite justify, will attend such efforts. It would seem to me to be more in accord with the dictates of true science to proceed in a different way, as indeed many workers have already been doing. To start not

from preconceptions based upon limited palæontological data, but from an intensive study of the living plants themselves. To widen as far as possible the criteria of comparison, by making, for instance, every possible use of cellular, physiologico-chemical, and especially secretory detail, and of minor formal features, such as the dermal appendages, or by initiating a new developmental morphology of the flower from the point of view of its function as a whole: and with its physiological end clearly in sight, viz., the maturing, nourishing, and placing of new germs. To make on some such basis intra-ordinal, and intra-generic comparisons with a view to the phyletic seriation of closely related forms; and so to construct probable short series, which may subsequently be associated into larger phyletic groupings. This should be checked wherever possible by physiological probability. A keen eye should be kept upon such information as geographical distribution and palæontology may afford, and especially upon the fossils of the Mesozoic Period. What is above all needed for success among the Angiosperms is new criteria of comparison, to meet the far-reaching difficulties that follow from parallel development and recent adaptation. If some such methods be adopted, and strenuously pressed forward, the task should not appear hopeless, though it cannot be anything else than an arduous one.

I cannot conclude without some remark on the bearing of parallel or convergent development, so fully exemplified in the Filicales, upon the question of the genesis of new forms. Anyone who examines, from the point of view suggested in this Address, the larger and well-represented divisions of the Vegetable Kingdom must be impressed with the extraordinary dead level of type to which their representatives have attained. In most of these divisions the phyletic history is obscured, partly by the absence of any consecutive palæontological record, but chiefly by the want of recognised criteria for their comparison. This is very prominently the case for the Mosses, and the Angiosperms.

But it may be doubted whether these large groups differ in any essential point, in respect of the genesis of their multitudinous similar forms, from the Filicales, in which the lines of descent are becoming clearer through additional knowledge. Suppose that we knew of no fossil Ferns; and that none of the early Fern-types included under the term 'Simplices' had survived in our living Flora: and that the Filicales of our study consisted only of the 2,500 living species of the old undivided genera of *Polypodium*, *Asplenium*, *Aspidium*, and *Acrostichum*. Then the phyletic problem of the Filicales would appear as obscure as does that of the Mosses, or of the Angiosperms of the present day. They would present, as these great groups now do, an apparent dead level of sameness in type, though the phyletic starting-points in each may have been several and distinct. There is every reason to suppose that in the phylesis of the Mosses or the Angiosperms also there has been a parallel, and even a convergent, development of the same nature as that which can be cogently traced in the Filicales: but that it is obscured by the obliteration of the early stages. Internal evidence from their comparative study fully justifies this conclusion. How, then, are we to regard this insistent problem of parallelism and convergence from the point of view of genetic study?

A belief in the 'inheritance of acquired characters,' or, as it is sometimes expressed, 'somatic inheritance,' is at present out of fashion in some quarters. But though powerful voices may seem to have forced it for the moment into the background, I would take leave to point out that such inheritance has not been disproved. All that has been done, so far as I understand the position, is to show that the evidence hitherto advanced in support of it is insufficient for a positive demonstration. That is a very different thing from proving the negative. We hear of 'Fluctuating Variations' as distinct from 'Mutations'; and it is asserted that the former are somatic, and are not inherited, while the latter are inherited. This may be held as a useful terminological distinction, in so far as it accentuates a difference in the heritable quality. But it leaves the question of the origin of these heritable 'Mutations' quite open. At the present moment I believe that actual knowledge on this point is very like a complete blank. Further, it leaves indefinite the relative extent and proportion of the 'Mutations.' It is commonly held that mutations are considerable deviations from type. I am not aware that there is any sufficient ground for such a view. It may probably have originated from the fact that the largest are most readily observed and recognised as reappearing in the offspring. But this is no justification for ignoring the possibility of all grades of size or importance of heritable deviations from type.

On the other hand, adaptation, with its consequence of parallel or even convergent development in distinct stocks, is an insistent problem. The real question is, What causes are at work to produce such results? They are usually set down to the selection of favourable divergences from type out of those produced at random. But the prevalence of parallelism and convergence suggests that those inheritable variations, which are now styled 'Mutations,' are not produced at random. The facts enforce the question whether or not they are promoted and actually determined in their direction, or their number, or their quality, in some way, by the external conditions. Parallelism and convergence in phyletic lines which are certainly distinct impress the probability that they are. Until the contrary is proved it would, in my opinion, be wiser to entertain some such view as a working hypothesis than positively to deny it. Such a working hypothesis as this is not exactly the same as a 'mnemic theory,' though it is closely akin to it. It may perhaps be regarded as the Morphologist's presentation, while the mnemic theory is rather that of the Physiologist. But the underlying idea is the same—viz., that the impress of external circumstance cannot properly be ruled out in the genesis of inheritable characters, simply because up to the present date no definite case of inheritance of observable characters acquired in the individual lifetime has been demonstrated. Of course, I am aware that to many this is flat heresy. At this Meeting of the Association it amounts almost to high treason. I plead guilty to this heresy, which may by any sudden turn of observation be transformed into the true faith. I share it in whole or in part with many botanists, with men who have lived their lives in the atmosphere of experiment and observation found in large Botanic Gardens, and not least with a former President of the British Association—viz., Sir Francis Darwin.

It is noteworthy how large a number of botanists dissent from any absolute negation of the influence of the environment upon the genesis of heritable characters. Partly this may be due to a sense of the want of cogency of the argument that the insufficiency of the positive evidence hitherto adduced justifies the full negative statement. But I think it finds its real origin in the fact that in Plants the generative cells are not segregated early from the somatic. In this respect they differ widely from that early segregation of germ-cells in the animal body, to which Weismann attached so much importance. The fact is that the constitution of the higher Plants and of the higher Animals is in this, as in many other points, radically different, and arguments from the one to the other are dangerous in the extreme. Those who interest themselves in evolutionary questions do not, I think, sufficiently realise that the utmost that can be claimed is analogy between the higher terms of the two kingdoms. Their phyletic separation certainly dates from a period prior to that of which we have any knowledge from the fossil record. Let us give full weight to this fact, as important as it is indisputable. The early definition of germ-cells in the animal body will then count for nothing in the evolutionary problem of plants. Moreover, we shall realise that the plant, with its late segregation of germ-cells, will present the better field for the inquiry whether, and how far, the environment may influence or induce divergences from type. From this point of view the widespread opinion among botanists that the environment in some sense determines the origin and nature of divergences from type in Plants should command a special interest and attention.

I must now draw to a close. I have passed in review some of your more notable plants, and pointed out how the Australasian Flora, whether living or fossil, includes in unusual richness those evidences upon which the fabric of evolutionary history is being based. I have indicated how this history in certain groups is showing ever more and more evidence of parallel development, and that such development, or convergence, presses upon us the inquiry into the methods of evolutionary progress. The illustrations I have brought forward in this address clearly show how important is the positive knowledge derived from the fossils in checking or confirming our decisions. Palæophytology is to be prized not as a separate science, as, with an enthusiastic view restricted between blinkers, a recent writer has endeavoured to enforce. To treat it so would be to degrade it into a mere side alley of study, instead of holding it to be the most positive line that we possess in the broad avenue of Botanical Phylesis. An appreciation of such direct historical evidence is no new idea. Something

of the same sort was felt by Shakespeare three centuries ago, and it remains the same to-day. Nay more :—it may lead us even to forecast future possibilities. In following our evolutionary quest in this spirit we shall find that we are indeed—

'Figuring the nature of the times deceased,
The which observed, a man may prophesy
With a near aim, of the main chance of things
As yet not come to life.'
(King Henry IV., Part II., Act iii., Scene i.)

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *The Double Stock—Its History and Behaviour.* *By* Miss E. R. SAUNDERS.

There is some evidence that the cultivation of the garden Stock dates back to Greek and Roman times, the double-flowered plant being then unknown and presumably not in existence.

There appears to be no definite record of the time or place of first appearance of the double form, but for various reasons we may conclude that it made its appearance only shortly before the date when it is first mentioned (middle of sixteenth century). A comparison of the frequency of reference to the double form of the three genera included at this time under the same name (*Leucoium* or *Viola*), viz., the Violet, the Wallflower, and the Stock, seems to show that they arose successively in the order named.

The original method of propagation of the double Stock (which is sterile) was by slips or cuttings, the double having appeared first in the biennial types. The fact that the double was obtainable from the seed of singles was not generally known for more than a century after the plant was in cultivation. Many different methods of procedure and treatment have been advocated from time to time as leading to the production or increase of double-flowered plants, but none have stood the test of experiment.

Mendelian methods of analysis have enabled us to arrive at an understanding of the relation of the double to the single, and have shown that the output of doubles is constant and independent of external conditions. By appropriate selection, in some cases of seeds, in others of the young plants, it is sometimes possible to obtain, not an increased output of doubles by the individual, but an increased proportion of double plants in the flower-beds.

2. *On the Sex Dimorphism and Secondary Sex Characters in some Abnormal Begonia Flowers, and on the Evolution of the Monœcious Condition in Plants.* *By* C. I. BOND.

In certain Begonias the presence of an abnormal floral bract frequently indicates an associated abnormality of the sex organs in the flower which terminates the pedicle on which the abnormal floral bract appears. This abnormality may take various forms, from simple multiplication or modification of accessory floral parts to complete hermaphroditism. The relative position of the male and female sex organs on the floral axis indicates whether the flower is primarily male or primarily female.

The Terminal Position of the Male Flower in the Normal Begonia Inflorescence.

The diœcious, the monœcious, and the hermaphrodite forms of sex dimorphism are the result of a process of qualitative cell division among different cell units, at different stages of their development. This sex differentiating cell division

may occur in the germ-cell and produce the diœcious form, or it may occur during flower bud differentiation and produce the monœcious condition, or it may be delayed to a later stage when the sex organs are differentiated on a common floral axis. The hermaphrodite flower is then formed. The actual disposition of the male and female sex organs may also follow one of two types: (*a*) Femaleness central and terminal and maleness peripheral and lateral, as in many inflorescences and probably all hermaphrodite flowers; (*b*) Maleness central and terminal and femaleness lateral and peripheral, as in many inflorescences of the monœcious type and in some abnormal Begonia flowers. The type assumed, primarily female or primarily male, will depend on the position taken by the factors for maleness and femaleness respectively during the differentiating cell division, and on which factor passes into the terminal and which into the lateral daughter cells.

The Bearing of these Facts on Plant Evolution.

The monœcious condition is probably an intermediate and unstable stage.

The hermaphrodite flower (which is probably the result of necessity for adaptation to insect fertilisation) has been brought about by delaying the segregation of the ♂ and ♀ sex organs till the period of the development of the flower. Probably also some hermaphrodite plants may have accelerated the process of sex differentiation. If this occurs early during the evolution of the inflorescence such plants would revert to the monœcious condition.

In animals postponement of the process of sex differentiation from the germ-cell to the zygote stage also produces hermaphroditism. Certain abnormalities in the distribution of secondary sex characters in the higher animals suggest that the development of the individual organism proceeds along two main lines, a segmental and a bilateral line. Lateral and segmental gynandromorphs are thus produced.

The Secondary Sex Characters of the Flowers of the Monœcious Begonia.

The two processes of qualitative cell division which result in (1) the differentiation of the ♂ and ♀ primary sex organs, and (2) the differentiation of the secondary sex characters, are less intimately interdependent in plants than in animals. This greater independence may depend upon the absence of, or the very restricted circulation of, internal secretions or sex hormones in the case of plants.

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3. *Some Account of the Flora of the Northern Territory.* *By* ALFRED J. EWART, *D.Sc., Ph.D., and* OLIVE B. DAVIES, *M.Sc.*

As is well known, the Commonwealth Government, since taking over the Northern Territory, has carried out a policy of energetically investigating the natural resources of this tract of country.

In addition to the expedition by Gilruth and Spencer, the Barclay expedition traversed a large part of the Territory, and Mr. Hill, the collector attached to the party, made large collections of plants.

Dr. A. Morrison was appointed to assist in the work of investigating these collections and the flora of the Territory generally. In July 1913 he published a Paper with Professor Ewart, 'Contributions to the Flora of Australia,' No. 21: 'The Flora of the Northern Territory (Leguminosæ).' Unfortunately, before he could publish anything further he became seriously ill, and died in December 1913.

Miss Davies was appointed successor to Dr. Morrison, and began work in February 1914.

Mr. Maiden has undertaken the investigation of the Myrtaceæ and of the Acacias, in which groups his knowledge is unrivalled.

The present Paper not only gives much additional information as to the distribution of the plants in the Territory, but includes several new species: among which are four new species of Leguminosæ, *Isotropis argentea*, Ewart and Morrison; *Jacksonia anomala*, Ewart and Morrison; *Psoralea luteosa*, Ewart and Morrison; *Tephrosia pubescens*, Ewart and Morrison; two new species of Proteaceæ, *Hakea digyna*, Ewart and Davies; and *Hakea intermedia*, Ewart and

Davies; the former being especially interesting as showing a tendency to fusion of the pedicels, thus forming two carpels on one pedicel or in one flower; and one new species of Chenopodiaceæ, *Atriplex varia*, Ewart and Davies.

Very little is known as yet as to the economic properties of the plants of the Northern Territory, more particularly as regards their fodder value or poisonous properties. In the present investigation special attention is being paid to those plants possessing either of these properties. Dr. Gilruth obtained data during his first visit of the food value of certain grasses, which have since been identified and published in the '19th Contribution to the Flora of Australia.'

Ewart and Morrison remark on the Leguminosæ:—

'The Leguminosæ include not only many of the most valuable fodder plants, but also many poisonous plants. Few of the plants on the present list have been tested as yet from this point of view, but poisonous species are known to occur in the following genera:—*Bauhinia* has three poisonous species, one of which is a fish poison, and another an anthelmintic, but no data are available for the species of this genus on the present list. *Brachysema undulatum* grows in other parts of Australia, and causes mechanical injury. *Canavalia obtusifolia* causes gastro-enteritis in stock.

Several species of Cassia are considered poisonous, and, according to Greshoff, this also applies to *Cassia Sophora* and *C. Sturtii*. No less than five species of *Crotalaria* are recorded as poisonous, and of these one, *C. Mitchelli*, grows in the Northern Territory. Three species of *Erythrina* and two of *Erythrophlœum* have been recorded as poisonous, but they do not include any of the species growing in the Territory. The Asiatic *Flemingia congesta* is a tænifuge, but the *F. lineata* of the Territory has not been tested. Many species of *Gastrolobium* are poisonous, but only one incompletely tested species (*G. grandiflorum*) is included in the present list.

Indigofera boviperda, however, has in West Australia been responsible for large losses of stock. The genera *Phaseolus, Psoralea*, and *Sesbanea* include poisonous species, but apparently none from the Territory. *Rhynchosia minima* is, however, poisonous according to Greshoff, and the same may be found ultimately to apply to some of the species of *Swainsonia* and *Tephrosia*. Several species of the latter genus are well-known fish poisons, and this applies to at least one species from the Territory, namely, *Tephrosia purpurea*. In this direction there is much work to be done in the future.

Included in the present work is a map illustrating the route taken by the expedition, and showing the more important plants collected at each station, that is, those which give some indication of the natural resources of the country.

4. *The Flora of the Environs of Melbourne.* By C. S. Sutton, *M.B., Ch.B.*

Introductory.—The consideration of our flora in its relation to the factors responsible and the estimation of these in explaining the distribution and association of its species have as yet been undertaken only tentatively.

Physiography.—The district to be considered is somewhat arbitrarily restricted to an area within a radius of almost thirty miles from Melbourne. The greater part of this is of low or moderate elevation and contains three main geological formations:—(1) From N.W. to S.W. a flat plain of the newer basalt gently sloping to sea-level from an elevation of almost 1,000 feet, drained by a simple river system in many places canyon-like.

(2) From N.E. a more diversified extent of Silurian formation, including, however, a considerable area of plutonic rocks where the highest elevations, 2,000 to 2,600 feet, are to be found; the whole drained by the Yarra and its tributaries.

(3) To the S.E. the area of Tertiary sands with an undulating surface rarely attaining 200 feet. Here the drainage system is ill-marked and over a great part hardly apparent.

Ecological Conditions.—(*a*) *Climatic*.—Although the rainfall is pretty evenly distributed over all the months, the bulk of it occurs in winter and spring. The average annual fall ranges from about 16 inches at the station in the basaltic area to more than 50 inches in the Silurian. Snow very rarely falls. The temperature only occasionally surmounts 100° F., and the highest temperatures do not long

persist. The mean annual humidity is high, and the annual evaporation low as compared with other parts of the Commonwealth.

(*b*) *Edaphic.*—The soil of the three areas presents well-marked differences. The influence of man and of the domestic animals is everywhere manifest.

Plant Formations.—The vegetation of the district is clearly divisible into three formations corresponding strikingly with the geologic formations. They would thus seem to be mainly determined by the soil conditions.

(*a*) That of the basaltic area, a grass steppe with low herbs and a minimum of tree-growth, occurring in savannah form and in the river bottoms.

(*b*) That of the Silurian area, a forest formation sometimes open but more often filled in with scrub and characterised by many species of Eucalyptus.

(*c*) The flora of the Tertiary sands, marked by a predominance of Epacrids, myrtaceous plants, and terrestrial orchids, constituting a scrub heath in *maquis* and separated from the strand by a belt of higher scrub containing several tree-forms.

(*d*) An association of halophytes peopling the strand and the salt-swamps at the mouths of watercourses.

Census.—Lists of plants from the three formations show the greatest variety in the forest area where the most favourable and varied conditions exist, and the smallest total in the basaltic area.

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5. *Australian Ebenaceæ.* *By* W. P. Hiern, *M.A.*, *F.R.S.*

The ebony family is represented in Australia by nineteen species, out of about 487 species in all. Twelve species are endemic in Australia. The Northern Territory, Queensland, and New South Wales supply the species. There are none in Tasmania.

In my Monograph of Ebenaceæ, published in 1873, I included among 262 recent species sixteen as occurring in Australia—ten of the genus *Maba*, and six of *Diospyros*.

Subsequent additions include two species, each contributing a genus to the Australian Flora. *Royena villosa*, a South African shrub, has been recorded from the Brisbane river in Queensland. *Euclea australiensis* was described by me in the 'Journal of Botany,' 1910, p. 159; the specimen was found among a set of Australian plants collected long previously by Sir T. L. Mitchell; it probably came from extra-tropical Queensland. A new species of *Diospyros*, *D. longipes* is the latest addition.

In 1879 Hans Molisch published a paper on the comparative anatomy of the timbers of Ebenaceæ and allies; this paper included an account of the minute structure of the stem of *Maba obovata*.

In 1892 Paul Parmentier published a work on the comparative histology of Ebenaceæ; in this work he favoured the view that every good species can be easily defined by the epharmotic characters belonging to it. His researches dealt exclusively with the leaves and stems. With regard to the leaves the parts which he studied were: 1. The upper and lower epidermis. 2. The blade, sections being made at different places along it. 3. The mid-rib and lateral veins. 4. The petiole, at the base of the blade, and in transverse sections. With regard to the stems, he studied all the tissues shown by transverse sections, and by radial and tangential sections of the liber and wood. Among the 120 species and varieties which he examined are *Royena villosa*, *Maba rufa*, *M. buxifolia*, *M. obovata*, *M. geminata*, *M. humilis*, *M. reticulata*, *Diospyros Ebenum*, *D. laxa*, *D. montana*, *D. pentamera*, and *D. microcarpa*.

For the present paper numerous original observations have been made in order to test and extend the epharmosis of the Australian species. The pollen also has been observed and measured in the cases of the *Royena* and *Euclea*.

According to Parmentier the two last-named genera are distinguishable from the rest of Ebenaceous genera by the periderm of the stem arising from the pericycle, instead of being sub-epidermal.

Hypoderma (arranged in a single row in both faces of the leaves) exists in *Maba humilis*, in which species also the cells of each epidermis are undulate.

Stomates are furnished only on the lower face of the leaves; they are numerous and correspond to the Ranunculaceous type, and are mostly sub-epidermal,

or in a few species immersed, or (among Australian species) are exserted in *Diospyros laxa.*

The mesophyll is bifacial in the majority of species, but sub-central in *D. pentamera.*

The palisade cells are usually arranged in a single row, but in the leaves of *D. microcarpa* they are in two rows, and a similar biseriate arrangement has been observed in the leaves of *D. longipes.*

MONDAY, AUGUST 17.

The following Papers were read:—

1. *Modern Derivatives of the Matonioid Ferns.* *By* Professor F. O. Bower, *Sc.D., F.R.S.*

Cheiropleuria bicuspis (Bl.), Presl, is a fern of the Malayan region, and is often associated locally with *Dipteris.* It is known chiefly from the drawings of Sir W. Hooker, and has not been submitted to recent comparative examination.

On material supplied, through the influence of the Rajah of Sarawak, by Mr. Moulton, keeper of the Museum, it has been found that it shows characters relating it on the one hand to *Gleichenia, Matonia,* and *Dipteris,* on the other to *Platycerium.* It is, in fact, a synthetic type.

Its creeping or scandent axis bears alternate leaves, with occasional abaxial buds on their bases, as in *Lophosoria* and *Metaxya.* The dermal appendages are hairs only. The leaf-form varies; the lamina, borne on a long petiole, may be one-, two-, or several-cusped; the venation is Matonioid of the type *Venatio Anaxeti.* The axis is protostelic, and the leaf trace originates as a single strand, as in *Mertensia.* It divides in the cortex into two, and undergoes further fissions and fusions in its upward course.

The leaves are dimorphic, the sporophylls being taller and upright, but with narrow lamina, marked usually by a strong midrib and enlarged margins. The intervening area appears covered by an 'acrostichoid' soral area.

Detailed examination shows that the sorus is of the 'mixed' type with numerous paraphyses. The sporangia share with those of *Dipteris* a segmentation different from those of any other known Ferns; viz., by cleavage of the primordium by alternately inclined walls, to produce *two* rows of segments. Bipartition of the lower segments gives *four* rows of cells of the stalk, which is also a peculiar feature common to *Dipteris* and *Cheiropleuria.* The annulus shows slight obliquity, and is not completely interrupted at the insertion of the stalk.

The vascular supply beneath the sorus shows features which link with *Platycerium.* The nerve-endings, which curve downwards to the lower soral surface, show enlargement of the distal mass of storage tracheides. Occasionally this enlarged receptacular supply may extend from its own definite areola of venation, crossing the vein which limits it, into a neighbouring areola.

This arrangement is a very simple example of what is a regular rule in *Platycerium.* Here, in addition to the conducting reticulum of veins of the sporophyll, there is a receptacular vascular system, extended in a lower plane. This is composed of branches from the conducting system, which may ramify, and extend to considerable length. The definite sori are seated upon these receptacular veins. These and other characters indicate that there is a real relation between *Cheiropleuria* and *Platycerium.* The comparative conclusion is this: That probably the whole of the Ferns above named sprang from a Gleichenioid source. That *Matonia* is the most primitive of these genera; *Dipteris* a more advanced type leading to a state with webbed leaves, and a spread of sorus over the leaf area. That *Cheiropleuria* retains the Gleichenioid anatomy, but has progressed sorally to an 'acrostichoid' state. That *Platycerium* is another derivative of this phylum, anatomically far advanced: it is also advanced sorally, though not to the 'mixed' and 'acrostichoid' condition seen in *Cheiropleuria.* Thus *Cheiropleuria* and *Platycerium* are probably modern Matonioid types, and it is possible that certain other living genera will also link on to this affinity.

2. *On Oxidase Enzymes.*
By Professor Alfred J. Ewart, *D.Sc., Ph.D.*

Plant oxidases form a class of substances of great importance in plant metabolism. They are known merely by the reactions they cause, and their exact chemical nature is quite uncertain. According to Bach and Chodat they form three distinct classes of ferments, namely :—

(1) Oxygenases, proteins which absorb molecular oxygen forming peroxides.

(2) Peroxidases, which increase the oxidising power of peroxides and can only act in their presence.

(3) Katalases, which destroy peroxides with an evolution of oxygen.

It has long been known that certain of the reactions supposed to characterise oxidase ferments could be produced by certain inorganic metallic salts. As the result of the detailed investigation of the oxidase action of various metallic salts of copper, iron, chromium, manganese, lead, &c., upon guaiacum, paraphenylendiamin, hydroquinone, pyrogallol, gallic acid, tannic acid, and tyrosin, the conclusion has been formed that the correspondence between the action of organic and of inorganic oxidases is extremely close. It was also found that in the case of certain salts such as sodium or potassium ferrocyanide, ferricyanide, phosphate, or chromate, the oxidase action was due to the acid, and not to the base. In addition, oxidase action may be accelerated in the presence of sensitisers such as the chlorides or phosphates of sodium or potassium, or may be retarded or prevented by a variety of anti-oxidases. This applies to both organic and inorganic oxidases, and determinations of the minimal amounts of metallic oxidases required to produce progressive oxidation in the presence of a sensitiser indicate that their action can be considered as closely akin to that of an enzyme.

In general, oxidases, whether inorganic or organic, may vary from strong to weak. The strong will cause direct oxidation from the oxygen dissolved in a watery solution. The weak will transfer oxygen from labile oxygen compounds such as hydrogen peroxide, or will use dissolved oxygen in the presence of sensitisers such as the chlorides or phosphates of sodium or potassium. Various intermediate grades of activity are shown. The oxidase action of a metallic salt varies according to its acid combination, and metals such as iron or chromium may give salts an oxidase action when the metal is present as base or as acid (potassium ferricyanide, bichromate, &c.). There is no reason for separating oxidases and peroxidases as distinct classes of ferments, and peroxides do not necessarily take part in all oxidase actions. The supposed separation of oxidase and peroxidase by fractional precipitation with alcohol may be merely the result of attenuation. Metallic oxidases act as ferments in that a small amount may produce considerable oxidation, especially in the presence of sensitisers (copper sulphate and salt, potassium ferricyanide and sodium phosphate), and that the oxidase appears to act as an intermediary in the chemical change. Nitric acid and potassium permanganate, on the other hand, transfer oxygen in the first instance from themselves.

Hydrogen peroxide may influence oxidase action (*a*) by providing a supply of labile oxygen; (*b*) by converting a feeble oxidase into a strong oxidase (ferrous salt into ferric, ferrocyanide into ferricyanide); (*c*) by acting as a sensitiser to the oxidant substance; (*d*) by acting as an anti-oxidase in some cases. Various salts may act as sensitisers (sodium and potassium chlorides, bromides, and phosphates) or as anti-oxidases (barium chloride, sodium fluoride, organic or inorganic acids), and in some cases with increasing concentration the action of the former is reversed, while a substance which is a sensitiser with one oxidant may act as an anti-oxidase with another. This applies also to the peroxide of hydrogen, and, in the presence of an excess of this substance, an oxidase may act as a reducing agent (copper sulphate and salt on indigo carmine). Strong metallic poisons will arrest the action of organic oxidases or destroy them (apple, potato, carrot, parsnip), if immediate contact or rapid penetration is assured. Hence the organic oxidases are possibly proteids with or without oxidase metals in basic or acid combination.

There is no justification for the use of such terms as 'peroxidase,' 'katalase,' 'œnoxydase,' or 'tyrosinase' to indicate specific substances, ferments, or

groups of ferments. The 'tyrosinase' of the potato is also a 'katalase,' a 'peroxidase,' a 'pyrogallase,' a 'hydroquinonase,' and a 'paraphenylendiaminase.' It is, however, permissible to use such terms as katalase action, peroxidase action, and such names as laccase, russulase, potatase, carrotase, &c., as temporary names to indicate the origin of the substances whose chemical nature is as yet unknown. Since, however, their oxidase powers will be only one of many properties, it will never be advisable to name them according to these properties alone, any more than it would be in the case of the metallic oxidases. Comparison with metallic oxidases shows that we are not even on safe ground in assuming the existence of specifically distinct classes of plant oxidases, such as phenolases, aminoxidases, and iodoxidases. The chlorides and phosphates of potassium and sodium are able to act as oxidase sensitisers, and thus may influence special oxidations, or respiration in general. It is possible that they may exert a stimulatory or controlling action on plant metabolism and that the sodium chloride always present in the ash of plants may not be an entirely useless constituent. This may explain partly why small doses of salt stimulate the growth of many plants and why phosphates, in addition to being food substances, may act as stimuli to growth. The stimulating action of many metallic salts on growth may be partly due to their oxidase action.

Ursol tartrate turns lignified walls red or reddish brown. This is not an oxidase reaction, but is an admirable test for lignin, especially valuable for demonstrating the wood elements in pulpy tissue.

Chloroform strongly and ether more feebly retard or inhibit katalase action, but they do not suppress oxidase action. After prolonged contact, however, the organic oxidases are slowly attenuated and destroyed.

The liberation of iodine from potassium iodide may be used as a test for the presence of oxidases in living tissues, but does not indicate the existence of any power of producing peroxides. Dried organic oxidases may retain their properties for three weeks or more, and a glycerine extract for five or more months.

Where organic oxidases are destroyed by boiling this is probably the result of proteid coagulation. In spite of previous statements to the contrary, (1) oxidase enzymes are present in the pulp and rind of the orange and lemon, and in the stalks, but not in the bodies, of the endocarpal hairs; (2) oxidase enzymes are abundant not in the protoxylem of the carrot, but in the phloem and outer cortex.

The oxidases of the beet and potato appear to be related to one another and to be among the strongest plant oxidases. The nearest analogies to them are perhaps afforded by ferric salts and ferricyanides. If the special action of apple oxidase on tannic acid is due to the presence of a phosphatic sensitiser, it would be a feebler oxidase of the same type. Carrot and parsnip oxidases are a grade feebler but still react to guaiacum in the absence of a peroxide. Malt diastase is still weaker, and papain feebler still, while pepsin may show a weak peroxidase reaction with guaiacum but not any other oxidase action.

3. *Morphology and Anatomy of certain Pseudo-Monocotyledons.* *By* Miss E. N. Thomas *and* A. J. Davey.

The paper gave a preliminary account of some features of interest which have been disclosed in the course of an investigation into the anatomy and morphology of the seedlings of geophytic Dicotyledons including some pseudo-monocotyledonous forms. The latter have a single cotyledonary member terminating in a blade which is more or less bifid in *Ranunculus Ficaria* and *Anemone apennina*, but is undivided in *Conopodium denudatum* and *Cyclamen persicum*, the 'petiolar' region being much elongated in *Conopodium denudatum* and *Anemone apennina*.

A tuberous swelling arises while the seedlings are still quite young, before there is any sign of a plumule, and in *Cyclamen persicum* even before the cotyledon has emerged from the seed. At an early age the external appearance of the seedlings is very misleading, inasmuch as the position of the tuber is variously related to the *collet*, and hence the tuber would seem to occur in different morphological regions. The appearance of the plumule at the apex of

the tuber proves the tuber to be hypocotyledonary in origin, while the *collet* in some forms is situated in the cotyledon.

The anatomical investigation of *Conopodium denudatum* reveals the remarkable fact that root structure is present throughout the whole of the lower half of the 'petiole' of the cotyledon, and the same is true of *Anemone apennina*, while in *Ranunculus Ficaria* root structure is only found below the cotyledonary node. The plane passing through the two poles of the diarch primary root in these forms, also passes through the centre of the first plumular leaf, while in their normal dicotyledonous relatives, so far as examined (with the exception of one individual of *Anemone pulsatilla*) the diarch plate is at right angles to this plane, as in all diarch forms hitherto described. This is of interest in connection with the plane of formation of the diarch root in the true monocotyledons.

4. *On the Systematic Position of* Casuarina *and its Allies.* *By* Emily M. Berridge, *D.Sc., F.L.S.*

Since 1891, when Treub discovered chalazogamy in *Casuarina*, Engler, Wettstein, and other botanists have regarded the Amentiferæ as primitive forms directly descended from certain gymnospermous families.

The work of many investigators, however, has tended to show that the characters on which this view is based are not peculiar to Engler's class 'Verticillatæ,' or even to the Amentiferæ generally; and an examination of the structure of the inflorescence, flower, and cupule in the Fagaceæ seems to confirm the view, first brought forward by Hallier (but later discarded by him), that the ancestors of the Cupuliferæ were allied to the Rosaceæ.

5. *Description of some Fossil Fruits.* *By* Bertha Rees.

Fossil fruits were found in the shaft of the Langi Logan South Gold Mining Company at Ararat. They occurred in an old river deposit at a depth of some 236 feet from the surface, and were covered by two distinct basaltic lava flows. Many of them are of small size, being about one line in their greatest length, rounded in outline, and flattened. Each one appears to consist of two carpels, and has what may be the remains of a persistent perianth at the base.

There are also some fruits of a species of Casuarina and some fruits of Eucalyptus, and in addition other remains, such as a bud of a Eucalyptus flower, and what appears to be a portion of the rachis of an inflorescence of the same genus.

TUESDAY, AUGUST 18.

1. *Joint Discussion with Section D on the Nature and Origin of Species.*

The Origin of Species. *By* Dr. A. B. Rendle, *F.R.S.*

Use of the term 'species.'—The unit of the systematist who is required to catalogue the plants of various parts of the world as they are discovered. The 'species' of the monographer who studies critically an extensive series of specimens and recognises ultimate units widely differing in degree from well-marked species to subdivisions so critical that it requires an expert in the group to appreciate them.

Each species is eminently adapted to its environment; other than slight change of form or of arrangement of parts will tend to throw it out of tune with its environment, and therefore prove detrimental. To grow plants under alien conditions generally requires care and restriction of competition. The theory of descent implies a change in the species, and doubtless also in environment, but any change unless very slight or gradual would be detrimental.

On the theory of mutation species have not arisen gradually as the result of selection operating for a long period, but discontinuously by sudden small

changes or 'mutations,' which are given off in new directions and are inherited; they are distinguished from fluctuating or individual variability in which the variations are merely of a plus or minus character and are not inherited. The mutation gives rise to a new inheritable specific character, and is the source of the so-called elementary species. A comparison of these elementary species (*e.g.*, Jordan's *Drabas*) shows that their distinguishing features are precisely those which characterise fluctuating variability—relative size and degree of development of parts, hairiness, time of flowering, &c. Each species represents the resultant of a number of slight individual variations of already existing characters, and suggests some process of selection of a number of slight individual variations rather than a sudden mutation. A similar remark applies to the cases of seasonal dimorphism in alpine meadows described by Wettstein.

Sports or mutations arising under cultivation are of a different character, being generally marked by some one striking character such as cutting of the leaf, monophylly in species with compound leaves, &c. Generally speaking, such would not persist in Nature, especially where the floral organs were affected, as marked changes in these would be detrimental. These afford no evidence as to the origin of species in Nature.

Recently Lotsy has suggested crossing as the source of new species. Presumed stable genotypes or elementary species give rise when crossed to unstable heterozygotes which segregate into a new series of genotypes. There is no suggestion that the new batch of species is more in accord with environment than the parents, and there seems no reason for their persistence. In place of slight variations of well-adapted organisms this theory suggests for the operations of Natural Selection an indiscriminate series of new forms. Is there evidence for the occurrence of these hybrids or of these series of aberrant and largely monstrous forms in Nature in sufficient quantity to account for the origin of new species? Direct action of the environment an important factor in the origin of species.

2. *The Climate in Northern Temperate and Arctic Zones during the Latest Pleistocene Age.* *By* Professor Gunnar Andersson.

3. *The Geographical Distribution of the Sea-grasses.* *By* Dr. C. H. Ostenfeld.

4. *The Fossil Plants discovered by Captain Scott's last Expedition in the Antarctic Regions.* *By* Professor A. C. Seward, *F.R.S.*

WEDNESDAY, AUGUST 19.

The following Papers were read:—

1. *Relationship of Fungus and Alga in the Lichen-thallus.* *By* Miss A. Lorrain Smith.

General account of lichens and description of the composite thallus. Early theories and speculations recalled as to the nature of the different tissues, more particularly in the gelatinous lichens. The green cells determined by Wallroth to be brood-cells or 'gonidia,' a theory which was accepted for many years. Resemblance of the gonidia to free-growing aerial algæ more and more realised. Metamorphosis of the alga *Nostoc* to the lichen *Collema* finally observed by Stahl, who also likened the colourless filaments of the thallus to fungal hyphæ. An account of the culture experiments by which the alga was successfully isolated from the thallus by Speerschneider and observed by him to grow independently and to increase by division. Following the same methods, Famintzin and Baranetsky obtained the formation of zoospores in free-growing gonidia.

Various theories as to origin of gonidia. Culture experiments with lichen spores undertaken by Tulasne which seemed to prove that the gonidia were directly formed at the tips of the colourless hyphæ within the lichen thallus. Finally Schwendener's announcement of the dual theory of the lichen thallus: that the gonidia were algæ of independent origin outside the thallus, and that the lichen was therefore a composite plant formed from a fungus more or less parasitic on the gonidia or algæ.

Synthetic cultures undertaken by various workers to test Schwendener's theory with the result that in time numerous lichen plants were successfully developed, up to the fruiting stage, from lichen spores associated with algæ. Discussion thereafter centred on the exact nature of the association between the two organisms: whether parasitism of the fungus on the alga or a condition of mutual benefit described by Reinke as consortism, by De Bary as symbiosis? Various forms of contact between the two symbionts described and the effect on the alga.

The problem really one of nutrition. The fungus is certainly dependent on the alga; but the alga is also dependent on the fungus for nitrogen, and to some extent for carbohydrates as proved by recent research on the nutrition of algæ and lichen gonidia in varying conditions. Other instances cited of benefit afforded to green plants by associated fungi.

2. *The Contamination of Drinking Water by Algæ and its Removal.* *By* Professor T. Johnson, *D.Sc.*

An account was given of an important supply of water (360 million gallons) rendered highly objectionable for domestic use by the presence of a blue-green alga, *Oscillatoria tenuis* var. *natans*, which was shown, by dredging, to breed in the mud of the reservoir floor. Subsequently the weed floats and causes 'water-bloom' or 'breaking of the meres.' Its accumulation in stored water gives it an oily, fishy odour, and also puts the filter-beds out of action.

One to 10 lb. of copper sulphate per 1,000,000 gallons removes the nuisance without injuring man or fish, as Moore and Kellermann first showed

The paper illustrated the necessity of supplementing the usual chemical and bacteriological examination of water with a biological one.

Sydney.

Friday, August 21.

After the President had delivered his Address (see p. 560), the following Papers were read:—

1. *The Species Concept, with especial reference to Eucalyptus.* *By* J. H. Maiden.

The paper opened with a statement that the subject, though often debated in Europe and America, has been rarely discussed in Australia. The difficulties presented by homoplasy were then referred to. The proposition of no fixed line of demarcation between species was then discussed, and the writer's use of concentric circles to illustrate the affinities of allied species was referred to. The difficulties presented by such large genera as *Hieracium*, *Aster*, *Salix*, and *Rubus*, as well as *Eucalyptus*, were then emphasised.

The aid of anatomy and physiology, and indeed other methods, in our quest for truly natural species was then discussed. The Jordanian species were referred to, and Darwin's dictum was quoted that as regards species our troubles come from trying to define the indefinable. Species-making being a form of empiricism, there are two camps of honest workers, the 'splitters' and the 'lumpers,' and the mistakes that are made are the result of existing conditions.

The writer then explained in detail, as regards Eucalyptus, the plan of his

critical revision, pointing out that no line of study which promised to throw light upon the genus had been neglected. He emphasised the point that a species must be judged as a whole, and illustrated this by analogies from the science of history, from literary criticism, and from industrial legislation, pointing out in proportion as a botanist grasps all the facts concerning a species, he becomes a broader minded man. Although endless fun can be poked at the illogical positions in which we sometimes find ourselves by our conception of species, it is idle to attempt to abandon them, for plants will be labelled species on the evidence of our senses to the end of time.

The writer concluded with a reference to the services of the great European herbaria in naming and preserving the types of Australian species at a time when there were no means of preserving such types in Australia herself, and entered a plea that as a recrudescence of botanical expeditions to Australia has now set in, our colleagues in Europe and America should see that specimens of their types are made available in some parts of this continent.

2. *The Correlation between the Specific Characters of the Tasmanian and Australian Eucalypts. By* R. T. Baker, *F.L.S., and* H. G. Smith, *F.C.S.*

In this paper the authors brought under review the results of their recent research on Tasmanian Eucalypts, comparing them with their own earlier work on the Eucalypts of the mainland, supplemented by more recent data. The ground covered by these investigations, now extending over a period of a quarter of a century, embraces almost the whole geographical range of the genus—an area of the earth's surface of about 3,000,000 square miles. Such an area includes a diversity of soils, climates, altitudes, &c., and naturally one looks for and finds a great variety of species, but it is found at the same time that a relative constancy of specific botanical features and chemical constituents characterises the whole genus.

Comparisons, as well as contrasts, were made between the morphological and chemical features of the trees found at the sea-level and right up to the highest altitudes at which the correlated species occur both in Australia and Tasmania.

Most interesting results have been the outcome of this work, and a theory is now advanced of the geological age of the Tasmanian trees in comparison with those of the mainland. It is also attempted to show that in the Tasmanian Eucalypts we have the more recently evolved of the whole genus.

3. *Notes on the Evolution of the Genus Eucalyptus. By* R. H. Cambage, *F.L.S.*

A feature of the genus Eucalyptus is its wonderful adaptability to environment, and a brief sketch will show some of the changes it has undergone.

We have fossil evidence of its existence in Australia since late Eocene or early Miocene, at which time our present mountain system had not developed, and the climate was a mild to warm one. Eastern Australia was then fairly level, and in early Eocene was largely composed of siliceous soils, much of the silica being in a free state, rendering the soils sandy. Subsequent lava flows and deposits of volcanic tuffs yielded a more basic soil, and the final uplift, parallel to the east coast, towards the close of the Tertiary, produced elevations which have a cold climate.

Apparently the early Eucalyptus flourished in a sandy soil with a warm climate in Northern Australia. The bark was scaly to rough, the leaves opposite, sessile, horizontal and generally cordate, and often covered with stellate hairs or coated with caoutchouc. The leaves had a transverse venation, the numerous lateral veins forming an angle of about 65 degrees with the midrib. The flowers were large as compared generally with those of the genus at the present day, and possessed anthers which opened longitudinally in parallel slits. The fruits were generally larger than those of the more recent species to-day, and the chief constituent of the essential oils contained in the

leaves was pinene. With some alteration in environment, partly climatic and partly through the advent of more basic soils resulting from volcanic outpourings, a new development took place in the genus, and species were evolved with hard furrowed, fibrous or smooth barks. The mature leaves, which now showed a more oblique or diagonal venation, and were alternate, had gradually developed petioles, which allowed them to hang vertically, so as to present the least possible surface to the sun and thus minimise transpiration, while those which remained sessile protected themselves with a glaucous powdery wax or with a thickened epidermis. Some species of this new type possessed anthers which opened in terminal pores, while cineol became an important constituent of the essential oils. As the genus encountered colder conditions, partly through spreading southwards and partly through ascending the mountains which were uplifted in Eastern Australia towards the close of the Tertiary, a further group was evolved having leaves with almost parallel venation, or the lateral veins now much reduced in number, at an angle of less than about 25 degrees with the midrib, kidney-shaped anthers with the cells divergent at the base and confluent at the summit, and essential oils in the leaves containing much phellandrene, and little, or in some cases no pinene. By a comparison of seedling and mature foliage, evidence of transition in leaf form is found in nearly all species, and in the cold-country types, such as *Eucalyptus coriacea* and *E. stellulata*, the lateral veins of seedling foliage are arranged at angles up to 50 degrees with the midrib, while in mature leaves the angles are less than 10 degrees, and in most cases the veins are practically parallel with the midrib. Eucalyptus leaves with transverse venation are absent from Tasmania, are confined to a very small portion of North-eastern Victoria and practically below the 3,000-foot level in New South Wales, but are common on siliceous soils in Northern Australia, thus showing a preference for the warmer climate. Eucalyptus leaves with parallel venation occur in Tasmania, Victoria, and Eastern New South Wales, while in Northern New South Wales their home is above the 3,000-foot level; and they are absent from Northern and Western Australia, but are found at the highest point that any Eucalyptus grows in Australia, viz., 6,500 feet, thus showing a preference for cold and moist conditions.

4. *Variation and Adaptation in the Eucalypts.* *By* Dr. Cuthbert Hall.

Eucalypts have always been credited with an excessive tendency to variation. However, many of the so called variations should more properly have the terms deviations or fluctuation variations of De Vries applied to them. These, are responses to physical conditions to which the genus is particularly sensitive. Apart from these deviations there are many instances where two or more forms closely approach each other. Some of these which were classed as varieties should now, in the light of fuller knowledge, be counted as distinct species. It is wiser to give specific rank wherever possible. Evolution and the production of variations seem to be still actively going on amongst the Eucalypts. Instances of variations may be given, among which is one I shall shortly describe—evidence of the cotyledon leaves as to variation and adaptation. In the *E. corymbosa* group these closely resemble those of the Angophoræ. Emargination has had a great influence on the evolution of the cotyledons and their adaptation to Australian conditions. This has gone on coincidentally with the evolution of other morphological characters and of the essential oils.

TUESDAY, AUGUST 25.

Joint Discussion with Sections C (Geology), D (Zoology), and E (Geography) on Past and Present Relations of Antarctica in their Geological, Biological, and Geographical Aspects.—See p. 409.

The following Papers were read :—

1. *The Vegetation of Gondwana Land.* *By* Professor A. C. Seward, *Sc.D., F.R.S.*

The geographical distribution of Permo-Carboniferous plants throughout the world is a subject on which much has been written in recent years, and evidence has been brought forward pointing to the existence of two botanical provinces—a northern flora illustrated by the coal-bearing strata of North America and Europe, and a southern flora obtained from strata in South America, South Africa, India, and Australia closely associated with glacial deposits. The object of this paper was to institute a general comparison of the vegetation characteristic of the two provinces with a view to determine in the light of our present knowledge (i) the degree of difference between the floras, (ii) the bearing of the facts on the question of climate, (iii) the relation of the Permo-Carboniferous flora of the southern hemisphere to older floras throughout the world.

2. *Recent Advance in our Knowledge of Sigillaria.* *By* Professor Margaret Benson, *D.Sc.*

After referring to the extraordinary habit of the plants included in this well-known genus, and its distribution in time, the author pointed out that the fructification of Sigillaria had been hitherto but very imperfectly known. Recently a better knowledge of the leaves and cones has been attained. The structure of the sporangia was then described and shown to be of exceptional interest.

M. Zeiller was the first to prove from incrustation specimens the general habit of the cone and form of the cone scale. Dr. Kidston had since demonstrated, also by incrustation specimen, certain characters of the sporange. The author has had for ten years some sections of a petrified sporange, but had no clue to its identity beyond the fact that it was Lycopodraceous.

Last year, however, from some 'coal balls' from Shore, near Manchester, sections were cut in the radial and tangential planes of similar sporangia, and at once the resemblance to Dr. Kidston's specimens of *Sigillariostrobus ciliatus* became apparent. No less than four petrified cones were shortly afterwards investigated, and found to agree in all main features with the Sigillaria cones of both Zeiller and Kidston.

Dr. Kidston's incrustation sporangia had been regarded as being immersed in the tissue of the sporophyll. In the new petrified material this appearance was shown to be possibly due to the wall of the sporange being carried out as a shovel-shaped expansion which exactly fitted into the concave upper surface of the sporophyll. The petrified specimens had been provisionally named Mazocarpon, or 'loaf-fruit,' from Mazé=a barley cake, because of the breadcrumb-like appearance of the sterile contained tissue.

Summary of evidence that Mazocarpon is a fructification of Sigillaria :—

1. Resemblance to Dr. Kidston's *Sigillariostrobus ciliatus.*

2. Resemblance of cone axis and bracts to both Zeiller's and Kidston's specimens. (The cones are pedunculate, show deciduous cone-scales and cone-scars of characteristic form and arrangement.)

3. Marked association with Sigillaria foliage leaves, and the bark of *Sigillaria mamillaris.*

The paper was illustrated by lantern slides and models.

3. *Types of Vegetation on the Coast in the Neighbourhood of Adelaide, South Australia.* *By* Professor T. G. B. Osborn.

The region under investigation is a sand-dune fringed strip of coast extending in a direction approximately North and South for about eighteen miles from Outer Harbour at the northern extremity of Lefevre's Peninsula to Marino, where the Cambrian rocks come down to the sea. The area is situated in

lat. 34° 56′ S. and long. 138° 35′ E., being a portion of the eastern shore of Gulf St. Vincent. The annual rainfall is about 18 inches, the bulk of which falls in the winter months, April to September. The summer temperatures may be high, not infrequently over 100° F. in the shade. The prevailing winds during the summer are S.W. to S., in the winter N.E. to N.

St. Vincent Gulf is of very recent origin,[1] and since Pleistocene times the coast has undergone several submergences and uplifts. The sand forming the dunes has been heaped up along the shores of the gulf against the seaward extension of the recent and Tertiary clays forming the Adelaide Plain. These clays are exposed by the drifting sand in small patches at the S. of the area. The dunes raised by the action of the S. and S.W. winds have been prevented from attaining any great height by the action of the strong N. and E. winds which blow at certain times. In the shallow waters of the Gulf are large areas of *Posidonia*, *Pectenella*, and *Zostera*, the débris of which, cast up by the tide, form long banks a foot or more thick and as much as 20 feet across at high-tide mark. These banks protect the dunes as well as forming a basis for new ones.

Vegetation.—In connection with the dunes the following communities[2] may be noted :—

Strand Plants.—*Atriplex cinerea*, *Salsola kali* and **Cakile maritima.*[3]

Mobile Dunes.—These are colonised chiefly by *Spinifex hirsutus*, which has stout, creeping rhizomes. **Ammophila arenaria* is planted in places, and is spontaneous on some mobile areas. The floor of a 'blow out' is usually first colonised by *Salsola kali.*

Static Dunes.—The greater part of the dune fringe may be described as static. *Spinifex hirsutus* frequently extends over the seaward face to the level of the strand flora. Associated with *Spinifex* and in part replacing it are many shrubs. Of these *Olearia axillaris* is the most important, but *Scaevola crassifolia*, *Alyxia buxifolia*, &c., also occur, and are all able to grow through sand deposited on them. Other plants include *Pelargonium australe*, *Lotus australis*, **Œnothera biennis* and *Senecio lautus.*

Fixed Dunes.—In addition to the plants mentioned above, and other shrubs, various Cyperaceous plants (*Scirpus, Lepidosperma*) and also *Dianella* occur. The radiating prostrate stems of *Mesembryanthemum æquilaterale* cover much ground and serve to bind the sand. Valleys of varying depth and width occur between the dunes. In the deeper ones shrubs are common, as above, with *Leucopogon Richei*, *Myoporum serratum*. The ground flora has many herbaceous plants and includes several aliens. The shrubby flora is not so characteristic of the more open valleys. These are colonised by *Mesembryanthemum æquilaterale* and ** Œnothera biennis*. The dunes remote from the sea are occupied by an open community of shrubby plants in which *Acacia salicina*, *Dodonea viscosa* appear; *Muehlenbeckia adpressa*, *Clematis microphylla* are woody climbers. Trees of *Eucalyptus odorata* and *Casuarina quadrivalvis* occur, and there is evidence that they were formerly more abundant.

Marine Salt-marshes.—These are developed on the landward side of the dunes in various estuarine areas.

Mangrove.—The portions subject to tidal scour are colonised by *Avicennia officinalis.* On the shoreward margin this is mingled with *Suaeda maritima.*

Salicornia Swamps.—*Salicornia australe* and *S. arbuscula* are the most important plants over large areas subject to occasional tidal inundation. Brackish swamps beyond the tide-limit are characterised by *Melaleuca pustulata* with Salicornias and *Frankenia lævis*, while *Mesembryanthemum australe* also grows on better-drained patches. These swamps may pass abruptly into sand-dunes or may show zoning, as (1) *Salicornia*; (2) *Salicornia* and *Samolus repens*; (3) *Samolus repens* and *Sporobolus virginicus*; (4) *Sporobolus*, *Spergularia*, &c., passing to dune flora.

[1] Howchin, *A.A.A.S. Report* 1913.

[2] The word 'communities' is used intentionally in preference to the term 'association,' which it is thought better to avoid in the present preliminary communication.

[3] Plants not recognised as native in South Australia are distinguished by * preceding the name.

Scrub Woodland.—The tendency to form scrub on settled dunes has been noticed. A woodland of *Callitris propinqua* formerly characterised much of the level area behind the dunes that is slightly raised above the level of the salt swamps, but few trees now remain. Under the influence of settlement the vegetation is either passing back to that of dunes or is becoming that of grass-land, largely composed of *Cynodon dactylon*, and *Sporobolus*, with tussocks of *Xerotes leucocephala*.

4. *On the Xerophytic Characters of* Bossiæa scolopendria (*Sm.*). *By* A. G. HAMILTON.

Bossiæa scolopendria is one of a group of leafless species of the genus, and is common on the Hawkesbury Sandstone formation in the neighbourhood of Sydney, and on the Blue Mountains.

It is leafless, but seedling plants have small elliptical leaves at first, and in very wet seasons leaves grow out on the mature branches in some instances. The leaves are set vertically on the branches, and have stomates on both sides, and yet the general appearance is that of a dorsi-ventral leaf, the midrib projecting on one side, the two halves being at an angle, and the colour differing, the side which should be lower being much lighter in colour.

The branches are flattened and winged, narrow in the lower part, but widening upwards to as much as three-quarters of an inch. The epidermis of the branches is covered with a network of ridges and, in the hollows between, the stomates occur. They are very numerous. The cuticle is fairly thick. The palisade tissue is closely packed round the stomates, and absent under the ridges. The individual cells are small in diameter and rather short. There is no distinct spongy tissue. The vascular system includes large areas occupied by sclerenchymatous fibres with thick walls and very small lumina. The whole of the tissues contain a good deal of tannin.

5. *Some Observations on the Life-history of* Ophiobolus graminis. (*Sacc.*). *By* Professor T. G. B. OSBORN.

6. *The Spores of Basidiomycetes.* *By* J. BURTON CLELAND, *M.D.*

This paper presented a study of the spores of various Basidiomycetes found growing in Australia. In the systematic classification of species, the remarkable diversity met with as regards the character of the surface and the shape of the spores led to speculations as to the importance of these and as to their value in showing specific and generic relationships. Though the results are inconclusive, the facts are of interest, and seem worthy of still closer investigation.

The spores have been considered from the following aspects:—(1) Size; (2) Colour in the mass; (3) Character of the surface; (4) General shape.

(1) *Size.*—The size of mature spores seems to be specific within varying limits. The dimensions vary in different species from about 2μ in some to 22μ at the other extreme (as seen in Australian specimens). Undoubtedly very closely allied species may show considerable differences in the dimensions of their spores (*e.g.*, *Stropharia semiglobata* and *S. stercoraria*).

(2) *Colour in the mass.*—This has been taken as a basis for the arbitrary classification of the Agarics. Though of practical value, it tends to associate widely separated genera and to dissociate closely allied ones (*e.g.*, *Lepiota* and *Psalliota*). Whilst white-spored species are, apparently, most numerous, various shades of brown are common. Brown spores are met with in the Agaricaceæ, Polyporaceæ, Thelephoraceæ, Clavariaceæ, and Gasteromycetes. Purplish or vinous-tinted spores are seen amongst the Agaricaceæ and Thelephoraceæ. As the loss or inhibition of colour is more likely to have taken place in the various sub-orders rather than its assumption in each case independently, the basic form from which the order sprang probably had coloured spores.

(3) *Character of Surface.*—This may be (*a*) smooth, (*b*) echinately warty,

(c) tuberculose. The majority of spores are smooth. Amongst the Agaricaceæ, whilst occasional genera are principally characterised by echinately warty spores (*e.g.*, *Russula*), in other genera they are rare (*e.g.*, occasional in *Inocybe*). In the Polyporaceæ occasional species of *Boletus* show this form; in the Thelephoraceæ, sometimes in *Thelephora* (usually more tuberculose); and in the Gasteromycetes they are common. The occurrence of peculiar nodulose or tuberculose spores in species of *Thelephora*, *Inocybe*, and several genera of pink-spored Agarics is surely more than a coincidence, indicating almost certainly a common ancestry. The paucity of species showing this character suggests its presence being a handicap to the maintenance of the species.

(4) *Shape.*—This may be (*a*) spherical, (*b*) somewhat pear-shaped (*Lepiota* type), (*c*) ellipsoid, (*d*) elongated ellipsoid, (*e*) fusiform ellipsoid (mummy-shape), (*f*) curved, and other modifications. (*a*) *Amanita* and *Amanitopsis* frequently show spherical or subspherical spores. (*b*) The pear-shaped *Lepiota* type is seen also in *Pholiota* and *Psalliota*, all ringed species macroscopically resembling each other, widely separated artificially by the colour of the spore-mass. The shape of the spores supports the general structure in indicating close generic affinities. (*c*) Ellipsoid—the most prevalent type amongst Agarics. (*d*) Elongated ellipsoid—appearing more in Polyporaceæ and Thelephoraceæ. (*e*) Fusiform ellipsoid—characteristic especially of *Boletus* and perhaps of mechanical advantage in the falling of a long spore vertically down a narrow tube.

7. *Potato Scab and its Causes.* *By* Professor T. Johnson, *D.Sc.*

An account was given of 'powdery' scab, due to *Spongospora subterranea*; of black scab, due to *Chrysophlyctis* (*Synchytrium*) *endobiotica*; and of some experiments to determine to what extent ordinary scab is caused by mechanical irritation.

WEDNESDAY, AUGUST 26.

The following Papers were read :—

1. *Inheritance in certain Giant Races of* Primula sinensis.[1] *By* R. P. Gregory, *M.A.*

Experiments have been made with two giant races of *Primula sinensis*, which have been shown to be in the tetraploid condition; that is to say, the plants have 4x (48) chromosomes in the somatic cells and 2x (24) chromosomes in the gametic cells, whereas in the ordinary (diploid) races of the species the numbers are 2x (24) and x (12) respectively. One of these races originated in the course of my own experiments from plants obtained in the F2 from a cross between two ordinary diploid races; the other giant race consists of the progeny of a plant very kindly given me by Messrs. Sutton & Sons.

The result of most general interest, which has been obtained from these experiments, is the discovery that the reduplication of the chromosomes has been accompanied by a reduplication of the series of factors. In the pure-bred diploid race each factor is represented twice, AA; in the tetraploid race it is represented four times, AAAA, and there are three distinct hybrid types, namely, AAAa, AAaa, Aaaa. These three hybrid types may, or may not, be identical in appearance, according as the presence of a single 'dose' of the factor is sufficient or insufficient for the perfect development of the character in the zygote; in either case they can be recognised by the progeny to which they give rise as a result of self-fertilisation. The hybrid AAAa gives no pure recessive types among its immediate progeny, but some of its offspring will give pure recessives in subse-

[1] A report of this work has been published in the *Proc. Roy. Soc.*, B, vol. lxxxvii., 1914, under the title 'On the Genetics of Tetraploid Plants in *Primula sinensis*.'

quent generations; the hybrid AAaa will give, on an average, one pure recessive in every sixteen of its offspring; while the hybrid Aaaa will, like the diploid hybrid Aa, give one pure recessive in every four plants.

Ratios of the form 15D : 1R, such as are obtained from the hybrid AAaa, recall those obtained in respect of certain characters by Nilsson-Ehle[2] in oats and wheat, and by East[3] in maize, but in the tetraploid Primulas the reduplication affects not merely the factors for isolated characters, but extends simultaneously to all the characters which have been studied. The numerical consequences of the reduplication of the factors are most conveniently studied in cases in which a single dose of the factor is sufficient for the development of the character, because one thus avoids difficulties of classification introduced by the occurrence of intermediate forms; characters which fulfil this condition in the giant Primulas are those of (*a*) thrum-eye or short-style, as contrasted with pin-eye or long-style, and (*b*) green-stigma, as contrasted with red stigma. Crosses between various plants having thrum-eye green-stigma and others having pin-eye red-stigma have given the two kinds of hybrid, TTttGGgg and TtttGGgg,[4] which have been identified by their progeny. The former gives an F2 ratio of 15D : 1R in respect of each character; the latter gives 3T : 1t and 15G : 1g. When the hybrids, instead of being self-fertilised, are crossed with the recessive, the type TTttGGgg gives offspring in the ratio 3D : 1R in respect of each character; while the hybrid TtttGGgg gives equality of thrum-eye and pin-eye and 3G : 1g. If the two characters are considered together, a hybrid of the type TtttGGgg would, in the absence of special inter-relations between the factors, give the curious F2 ratio 45TG : 3Tg : 15tG : 1tg; in the case under discussion, however, the results obtained indicate that a complication may be introduced by the existence of coupling between the factors for thrum-eye and green-stigma and further experiment is needed for their elucidation.

Other characters have been studied, in respect of which the hybrid is more or less intermediate between the two pure types. In the case of one character, namely, the palmate-leaf as contrasted with the 'fern-leaf,' dominance is complete in the diploid races, the hybrid, Pp, being indistinguishable in appearance from the pure palmate type, PP; but in the tetraploid races a series of curious intermediates has been obtained, which are probably of the constitution Pppp. In other cases where the diploid hybrid is intermediate, the corresponding form occurs among the tetraploid hybrids, but, in addition, there also occur peculiar intermediate forms, which are confined to the tetraploid races and are quite distinct from the diploid hybrid form. In the case of the factor which, in the homozygous condition, inhibits the production of colour in the petals, the tetraploid hybrid, Iiii, might, so far as appearances go, very well be classed as a coloured form; yet this ostensible recessive is capable of throwing the 'dominant white.'

The results so far obtained do not throw direct light on the problem of the possible relationships between factors and chromosomes. The fact that the reduplication of the chromosomes has been accompanied by a reduplication of the series of factors may, at first sight, suggest a close relation between the chromosomes and the factors; but, on the other hand, the tetraploid number of chromosomes may be nothing more than an index of the quadruple nature of the cell *as a whole*. There are, however, grounds for hoping that the further study of the genetics of the tetraploid plants, especially with reference to the special inter-relations between certain factors of which indications have been observed, may yield results having a direct bearing in connection with this problem.

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[2] 'Kreuzungsuntersuchungen an Hafer und Weizen,' I. and II. *Lunds Univ. Årsskrift*, 1909 and 1911; *Berichte d. Deutschen Bot. Gesellschaft*, xxix., 1911, p. 65.

[3] *American Naturalist*, xliv., 1910, p. 65.

[4] The hybrid type having three doses of either factor, TTTt or GGGg, is not produced by the mating of a dominant with a pure recessive, tttt or gggg. It can only be formed by the mating of plants producing gametes TT (or GG) and Tt (or Gg).

2. *A Botanical Survey of North-East New South Wales.* *By* Frederick Turner, *F.L.S., F.R.H.S.*

North-East New South Wales, considered from a botanical point of view, is one of the most fertile and interesting sections of country on the Australian continent. Reference is made to its area, configuration, soil, climate, and rainfall. Its flora, which is described as semi-tropical, being very dense and luxuriant in places, has occupied the author's attention since early in the 'eighties. A greater number of indigenous species of plants are growing there than on any other area of similar size in New South Wales. Much of the arboreal vegetation is festooned with immense and in many instances beautiful flowering climbing plants, and on the trunks and larger branches of some trees epiphytal orchids and ferns are growing plentifully, while the ground is literally carpeted with many species of terrestrial ferns. On one gigantic fig tree, *Ficus macrophylla*, Desf., more than two hundred epiphytal orchids and ferns have been observed. In different parts of this area there are magnificent forests of various species of trees, consisting of both hard and soft woods. The more important of the former are the species of *Eucalyptus*, and of the latter *Cedrela Toona*, Roxb. Other trees produce valuable, and in some instances highly ornamental, timber, suitable for many industrial purposes. The rarest and most remarkable tree of New South Wales is *Strychnos psilosperma*, F.v.M., of which botanical specimens are exhibited. According to Dr. James M. Petrie, F.I.C., it yields *strychnine*, *brucine*, and the newly discovered Australian alkaloid *strychnicine*. Reference is made to the medicinal value of *Duboisia myoporoides*, R.Br., and a number of other plants. Mention is made of the edible fruit and nut-bearing trees which once furnished food for the aborigines, the trees and shrubs with strongly scented bark and leaves, and also those which yielded dyes and fibres for the natives. The most conspicuous flowering tree is *Sterculia acerifolia*, A. Cunn. In the month of December it usually produces numerous panicles of rich red flowers, which have a charming and brilliant effect. *Leguminosæ* are widely distributed and are a conspicuous feature, consisting of trees, shrubs, and climbers, producing a profusion of various coloured flowers, mostly strikingly beautiful. Several species of *Hibiscus* produce very large and showy flowers, the most remarkable being *H. splendens*, Fraser. The palms, although they only number a few species, sometimes grow into miniature forests producing a decidedly tropical effect. Fern trees grow abundantly in many places, and some attain a considerable height. In the open country the forage plants and grasses form a large percentage of the vegetation, and are of great economic value. There are heaths of considerable extent which are covered with dwarf shrubs and herbaceous plants which produce a singularly beautiful effect when in bloom.

This is the first botanical survey of the North-East, and has added to the indigenous plants not previously recorded for New South Wales, twelve genera, sixty-nine species, and many new varieties. The number of Phanerogams and vascular Cryptogams in the North-East is 743 genera and 1,797 species.

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3. *Extra-tropical Forestry in Portugal.* *By* D. E. Hutchins.

Extra-tropical forestry in Southern Spain and Portugal has a peculiar interest for southern extra-tropical Australia, because the climate, the trees, and the forestry of both countries are (or will be) the same. Australia is now paying out about 3,000,000*l.* yearly for imported soft wood; and to produce this at home in the future (judging from the experiences of South Africa) Australia will have mainly to copy the forestry of Southern Europe. The writer, after a life-time in South African forestry, has recently completed a forest tour in Southern Spain and Portugal. The chief points of interest for Englishmen are these :—

The most important forest-tree, and the only abundant forest species in Portugal, is the Cluster Pine (*Pinus Pinaster*), the same tree which (under the name of the Maritime Pine) has transformed the dreary malaria-stricken 'Landes' of Southern France. It is the Cluster Pine also which, on its own merits, has become the most abundant coniferous tree in South Africa. The

Cluster Pine and the Stone Pine were introduced into South Africa some three hundred years ago; and have now become completely naturalised there, in the sense that they have taken the place of the weak natural forest flora of the country; and would remain there if the hand of man were withdrawn.

In the centre of a large pine forest area in Portugal is the State forest of Leiría comprising over thirty thousand acres. It has long been worked for timber of large dimensions; and is perhaps the best example of *a highly cultivated pine forest* in the extra-tropics. The temperature here is between that of Sydney and Melbourne; the rainfall is similar except that it falls almost entirely in winter. Timber of the finest description is seen in the Leiría forest, as fine as any timber in the best forest of central and northern Europe. I measured trees up to 35 inches diameter and 158 feet total height, and I saw great baulks of timber being taken out of the forest, such as one sees in the Black Forest of Germany. One usually associates Cluster Pine with pit-props, sleepers, and small timber; but the State Forest of Leiría produces pine timber which is used *for every purpose of house-building and furniture*. To protect the forest from fire during the dry summer weather, there is a complete system of fire-paths, watch-towers, and telephones. The area of private Cluster Pine forest in Portugal is very large. This is mainly occupied in providing mine-props for England. Not much resin is produced in either State or private forest in Portugal.

Cork Oak (*Quercus Suber*).—After the Cluster Pine the next most valuable forest tree in Portugal is the Cork Oak. The Cluster Pine and the Cork Oak together enable Portugal to export about 1,250,000*l.* worth of forest produce yearly.

Busaco Cedar (*Cupressus lusitanica*) has been naturalised in Portugal about the same time as the two pines in South Africa. My friend Dr. Henry has shown that it came originally from Mexico; it now produces the most valuable timber in the natural forests of Portugal. It should occupy a prominent place in any scheme of extra-tropical forestry. It is a most beautiful and valuable tree.

Stone Pine (*Pinus Pinea*).—This useful pine with its valuable nuts has suffered badly in South Africa from a fungoid disease; but in Spain and Portugal it is nearly free from it.

Aleppo Pine (*Pinus halepensis*).—This has certain advantages over Cluster Pine. It stands more drought, it will put up with lime in the soil, it transplants more easily; it is somewhat more shade-bearing. It is the species used for reforesting the devastated mountains of Southern Spain.

Oaks.—Five Oaks occur in Southern Portugal. The common British Oak (*Quercus pedunculata*) occurs as copse and scattered trees on good soil. Portugal pays heavily for cooperage wood, and wants a great deal more Oak.

Quercus lusitanica may almost be regarded as the extra-tropical form of the British Oak. It should occupy an important part in the future forestry of Australia. It has been nearly exterminated in Portugal precisely on account of its valuable qualities.

Quercus Tozza somewhat resembles the Durmast Oak of England; it is not often seen as a large tree, but makes valuable firewood copse.

Quercus Ilex.—The forest tree-planter in Australia and South Africa will generally prefer its first cousin, the Cork Oak; but the Ilex is somewhat hardier than the Cork Oak. It is the last tree left on the mountains in Southern Spain and Portugal, when fires and the axes and goats of the peasants have produced universal desolation. Its chief value lies in acorns for pig-feeding, and there is a variety termed *Ballota* which produces acorns nearly as sweet as a chestnut.

Chestnut (*Castania vesca*) seems steadily dying out in Spain and Portugal, as in other Mediterranean countries. The threatened loss of this valuable tree is one of the saddest features in modern European forestry. It may take a new lease of life in the southern hemisphere, care being of course taken (as with Eucalyptus in South Africa) to import the tree without its pests.

The Portuguese forest service is well organised, and the department generally far in advance of Britain and the self-governing British Colonies, except South Africa. It used to be customary in the forest text-books to place Spain, Portugal,

and the British Empire at the bottom of the list as regards effective State forestry. But forestry in Spain and Portugal is now a quarter of a century ahead of that of the British Isles; and many valuable lessons are to be learnt by those who can go to Spain and Portugal for the purpose of studying forestry. Portugal imports one-third million pounds' worth (against three millions Australia and thirty millions Britain) of forest products which, with good forestry, would come from the waste lands of each of these three countries. Portugal exports about one and a quarter million pounds' worth of forest products—cork, one million; Cluster Pine pit-props, &c., one-third million; against Australia one million and Britain nothing (the figures shown being re-exportations). Portugal and Australia have each a population of over four millions.

SECTION L.—EDUCATION.

PRESIDENT OF THE SECTION.—PROFESSOR J. PERRY, LL.D., F.R.S.

The President delivered the following Address at Sydney on Friday, August 21:—

I WISH to make some general remarks upon the Science of Education. As in the chapter which was entitled 'The Snakes of Iceland,' and which merely consisted of the sentence, 'There are no snakes in Iceland,' I might finish this Address at once by saying 'There is no science of education.' There is the art or practice of teaching or pedagogy, just as there used to be the art of engineering. It was only slowly that the subject of Section G, the Science of Engineering, was created; but the subject of Section L, this Section, has still to be created. In the creation of a science we first and for long periods have the observation of detached phenomena and disputes about them, because the phenomena seem complex, having no obvious connection with one another; then experiments simplify things, and gradually the science is created by inductive reasoning and research. In education, observation and disputes have occupied much time, and we cannot say that the phenomena have become much simplified by such experiments as have been made. Every man in the street considers that his opinions on education are as good as those of anybody else. I suppose that almost nobody would refuse to make an after-dinner speech on any kind of education, whereas he would not dream of speaking about geometry, or chemistry, or physics, or physiology unless he had studied these subjects. Any ordinary citizen thinks himself fit to be a member of the governing body of a school or college, and the disasters due to this belief are worse than what would occur if we gave to such men the command of ships. The ordinary man, especially the Parliamentary man, who thinks that the members of a committee on some scientific business ought all to be non-scientific men, will jeer at this statement, but it is, nevertheless, fatally true.

It is possible that, even if we had the science, the pedagogues would pay no attention to its principles, just as there are industrial chemists in London whose businesses are dwindling because they pay no attention to the science of chemistry. Pedagogy is in a worse condition than industrial chemistry, because chemical products can be easily tested as good or bad, whereas the pedagogic product is exceedingly difficult to test. The customer is the worst of judges. Those soul-destroying cheap schools described by Mr. Wells used to be very numerous; they are still, many of them, in existence. Every observant person knows of these places, to which small shopkeepers still send their sons, because they are genteel and cheap, and because Latin is taught, and perhaps French. Did any such parent ever object to the result of the schooling? Even when a boy has become a man, neither he nor his father knows whether his defects or merits are due to bad or good schooling. Please read Mr. Wells' book about Mr. Polly. Again, the reforms in pedagogy which, with Dr. Armstrong, I have been clamouring for during the last thirty years, would cause the best-known pedagogues to scrap all their machinery and so to lose nearly the whole of their invested capital. Even when they are not influenced by the idea of losing money, these men cannot be made to believe in the necessity for reform any more than the Central African worshippers of hideous idols can be converted, for with just

as much intensity do they worship the product of our present schools and colleges. The pedagogue is not alone in his false worship; this is the day of small men, commonplace men, men manufactured like so many buttons, so that it is almost impossible for a great man to appear; everybody is compelled by custom or by law to go to school, and the school ideal is just as false and mean and material as any false religion ever was. Every clever man who has gone to a public school and to Oxford or Cambridge worships the system which has taken from him his spiritual birthright, his individuality, his initiative, his originality, his common sense, his power to think for himself—yes, and I may say his belief in himself. He has become too much like a sheep, ready to follow the bell-wether; he is a man who has greatly lost his soul. Average boys leaving a public school all speak in the same way, in the same words, about anything. They are nearly as much alike as things manufactured by the same machine. An expert easily tells from what school a boy has come, because there is nothing left in his mind which is not common to the whole school.

The education given in England to boys till they leave school at twenty and till they graduate at a University is almost altogether classical: that is founded on the language and literature of Greece and Rome. On the day on which I wrote this there was a report of an address in *The Times* which said that this study was the cause 'of all imaginative aspirations, of all intellectual interests'; 'it enabled men to appreciate, not only Homer and Virgil, but equally Dante and Milton, Goethe, and Wordsworth, all the great thoughts of all ages and all lands, and to be awake to the movements of their own day.' It said that this study made a man 'a better man of business, a better lawyer, a better merchant, a better stockbroker, a less hidebound politician.' 'Those who would banish Greek or would make it the peculiar property of a select few did a grave disservice to the whole cause of intellectual and spiritual life.' The writer then described his own diligent reading in the train every morning; in the course of a few months he had read the 'Iliad,' the 'Odyssey,' the 'Aeneid,' five books of Livy, and the whole of 'Catullus' and 'Martial.' It seems almost as if he must have all extant classical literature off by heart. He must have enormous satisfaction as he sits in the train looking at the quite common travellers who are reading about the affairs of the nation in English newspapers. I quote the above statements because they are typical. All our classical friends say that sort of thing. But I do not pay much attention to them, because I know that the greatest classical scholars only devote themselves to editing some Greek text that has been edited over and over again. These men rave about the glory of youth and beauty as preached by the Greeks, but their enthusiasm is not shown in any practical way. We must believe that this enthusiasm exists, because these men tell us themselves that they experience it. But what is a fair man to say when he hears his friends talk of the beauties of Sophocles and Euripides if he knows that these friends never read Shakespeare, or Jane Austen, or Goldsmith, or Dickens? I have not referred to the fact that classical scholarship leads to power and wealth in the Church and State, to palaces and baronies, to purple and fine linen. Leaving such things out of account, I have a suspicion that this worship of classics is like one's fondness for the rhymes, often rubbishy rhymes, that associate themselves with our infancy and boyhood, or like Johnson's belief that his wife was amiable and beautiful. It is even possible that the very best scholar is of but little use to the world. It would be easy to show that, since the sixteenth century, the classical pedant has done little but to spoil the rich English language of our Bible. We want now a man like Bishop Pecock to delatinize our language.

Let us, however, consider a boy of another class—the boy called clever, say, one in twenty of the whole. At the age of twenty or twenty-one, stale and tired with the reception of ancient learning, of other men's thoughts, he gains a fine scholarship at the University, where he is supposed to be almost a free man, and all the use he can make of his freedom is to go on absorbing ancient learning, keeping his nose to the grindstone as if he were still a schoolboy. Treated as a boy from seventeen to twenty-one, he remains a boy till he is twenty-four, and he cannot help becoming a small-minded, though clever and learned, man, who fails to see that literature is no longer the possession of a small class. Yet if he had left school for the University at sixteen or seventeen we might hope that University freedom and association with others and with learned men might have made him great, a great poet, a man of cultivated imagination, fit

to become a great writer, a great philosopher, a great politician, a ruler of men. One of the curses of intellectual England is due to schoolmasters keeping men at school and treating them as boys to the age of twenty or twenty-one. They take scholarships as stall-fed cattle take prizes at agricultural shows.

Our famous writers had, like Burns, no school education, or else only a short school education. Boys went to the University too early after the Renaissance, and Bacon entered Cambridge at the age of thirteen. Shakespeare, thank God, was only at a grammar school, and is supposed not to have completed even that short course of school work. Even Ben Jonson, who was so proud of his learning and rather scorned Shakespeare for his 'small Latin and less Greek,' had only a short school education. Phineas Fletcher went to Cambridge at sixteen. Massinger went to Oxford at eighteen. Of the school time of some of our most original writers we have but little information, but that it must have been short we have indirect proof. Beaumont's first play was produced at the age of twenty-one. Waller entered Parliament and wrote his first poem at eighteen. Dryden went to Oxford at seventeen. Milton went to Cambridge at seventeen. Addison went to Oxford at fifteen. The whole of Pope's school education was four and a half years. Swift went to Dublin University at fifteen. Goldsmith, after a most erratic school time, entered Dublin when he was fifteen. Our present school system is to keep a boy with his nose to the classics grindstone from the age of eleven to the age of twenty, and copies the German system. The result is the same in Germany and England. Genius is very common in both countries, but 99 per cent. of it is destroyed by the schools. It is, however, when we come to study the average boy—nineteen in twenty of all boys—that the system looks most devilish. In Germany it is worse than in England. There even the average boy submits, and plods hard all the time, because there is a great reward for him —a diminution in his time of military service. Well, the result for the average German boy is that he becomes stupefied, dull, and loses all initiative. The average English boy gets much less of these evil effects, because he neglects his schoolroom work and keeps his mind active and his soul alive by means of football and cricket. It is from this great characteristic, that knowledge and wisdom come from doing and not from abstract reasoning, that the British race rules the world. We learn all that induces common sense from observation and experiment. I often used to observe that a boy whose face was attractive because of its brightness and intelligence in the cricket field, seemed when he entered my classroom as if an isolating veil of unintelligence suddenly covered his face. He had settled for life that he could not understand the classroom work, and he refused to make any more efforts. Even the clever boy's soul is to some extent protected by his sports, so that in every way less harm is done in England than in Germany. Still, the system produces, even from clever boys, only clever, dull men, fit to be barnacles in the public services. The system may be said to give a good training for lawyers—the necessary clever kind of lawyer of the Law Courts and Chambers who is mute in the House of Commons.[1] But it destroys the higher qualities of men and makes them narrow. It ought to be remembered that Lord Somers was the only great lawyer who was also a great man. Poor boys cannot get this

[1] The acuteness of a lawyer in finding the meaning of a document is very wonderful. Almost any mental power can be cultivated to such a very high degree that it almost seems diabolical. A trained person after passing a shop-window rapidly is able to describe every object in the window, although the objects may be very numerous and curiously different. Yet this same man may not be at all clever in other ways. In patent cases a clever judge takes in the most elementary scientific knowledge with very great difficulty. The readers of the hundreds of newspaper articles of any morning—as like one another as herrings—are awed with their display of culture, of depth of thought, of knowledge, and with, what is more astounding than anything else, an infinitely perfect Oxford polish. Watching the performances of an Oxford man of letters is like watching a good billiard player or a skilled musician. His mind is filled with the thoughts of other men, pigeonholed ready for use. It is extraordinary that a man can have been so educated as to be a good debater, to be able to make a fine speech, that he may have taken a degree at Oxford, that he may have passed examinations in classics, philosophy, and mathematics, and yet be exceedingly ignorant, illogical, and unscientific.

training unless they are so unlucky as to get scholarships, or are induced to attend University extension lectures; and it results that nearly all our best writers, writers with imagination and originality and initiative and individuality, have been boys of the common people. Although poor boys are most frightfully handicapped for the race to distinction, I do not think that the poor child is much handicapped by mere heredity, for he is naturally nearly equal to a boy of the highest lineage. Natural selection up to the time of the first great civilisations, when there were comfortable houses and palaces—say, 100,000 years ago—together with the effects since then of revolutions and wars of conquest, involving slavery of the conquered, have created a wonderful equality among the individuals of mixable races.

For the average boy at a public school the school work is a terrible uphill grind all the time; a soul-destroying, stupefying business, so stupefying that he makes no complaint, he merely suffers. He feels that he is a failure, learning nothing that can be of spiritual or material value to him in his future life. Of course, he can pass examinations; anybody can be crammed to pass an examination, but after the examination he forgets what he was supposed to have learnt.

The present system of education is to be condemned for other reasons. It is exasperating that all the most important, the most brilliant, the most expensively educated people in England, our poets and novelists, our legislators and lawyers, our soldiers and sailors, our great manufacturers and merchants, our clergymen and schoolmasters, are quite ignorant of natural science; and it may almost be said that in spite of these clever ignorant men, and men like them in other countries, through the agency of scientific men, all the conditions of civilisation are being transformed. I do not think that a fact of this kind would have been neglected by the philosophers of Greece (who scorned to know any other language than their own) or the learned men of Rome, but when some of us direct attention to it and its neglect by modern philosophers we are sneered at as Philistines. It is a curious kind of culture which scorns the lessons of history, the study of man in his relation to nature, the study of the enormous new forces which are now affecting the relations of nations to one another. How many of our rulers know the astounding fact that the cost of the most unskilled work done by man costs 1,000 times as much as when that work is done by a steam-engine? Hence it is that the steam-engine has given means for leisure and high culture, yes, and low culture and decadence, to hundreds of people instead of units. And the steam-engine enables rulers to spend a hundred times as much money on soldiers and sailors and ships and munitions of war as they did two hundred years ago.

The University man thinks that he can get some knowledge of science by reading, but without laboratory study he is like the man who said 'barley' when he wanted to escape from the robbers' cave and ought to have said 'sesame.' Do you know the ballad about Count Arnaldos, who envied the old helmsman his weird and wondrous powers?

> 'Would'st thou,' thus the helmsman answered,
>   'Learn the secret of the sea?
> Only those that brave its dangers
>   Comprehend its mystery.'

I know that the ordinary University man thinks, like the wistful Count, that he can get all things easily or by mere reading. But, in truth, to read the 'Origin of Species,' or treatises on astronomy or physics or chemistry, is a misleading performance unless the reader brings to the study that kind of mind which has been developed already by his own observation and experiment.

The University man, ignorant of science, becomes a ruler of our great nation, his duty during war and peace being that of a scientific administrator, and without turning a hair he fraudulently accepts this important duty for which he is utterly unfit. The gods must surely laugh when they see these rulers of ours gibing at scientific things, giving important posts to non-scientific men who scorn and obstruct the scientific men who are under their orders. If Oxford scholars were merely like so many monks in their monastery, living the lives and following the studies which they love, I would say nothing. The revenues so used up are, I think, of no great importance to the country, and busy men elsewhere can only be benefited in knowing that at Oxford and Cambridge there are these lovely lamaseries where men are living in serene air apart from the struggles of the

world, living what they think to be the higher kind of life, that of the amateur copying the lives of the scholars of Constantinople before they were so mercifully scattered in 1453, copying the meditative ways of the divines and hermits of the fourth and fifth centuries. Unfortunately the Oxford hermits have by a series of accidents become the rulers of the greatest empire that the earth has ever seen, and it is very obvious indeed through many other things than the starting of South African wars that they are unfit for their job.

If our rulers were like savage chiefs they might possibly give equal chances to candidates for posts; but unfortunately it is as if our leaders possessed great *negative* knowledge of Natural Science, and as if a man's chances of being appointed to a scientific post or of having his advice listened to were in inverse proportion to his scientific qualifications. Scientific men look around them and see that everything is wrong in the present arrangements, but they also see that it is useless to give advice which cannot be understood by our rulers. And, indeed, I may say that when by accident a scientific man is appointed on a committee there is a negative inducement for him to do anything.

Many men enter the services by examination, and it is always through cramming that they pass. In some cases the examination is supposed to be in science. In truth, the scientific habit of thought, the real study of science, the very fitness of a boy for entrance to the service, would unfit him for passing these abominable unscientific examinations. For some army posts, further scientific food is provided by the Government for the classical or modern language or science dummies after they enter the service. If one wishes to hear how evil this system of pretended education is, let him ask the opinion of some of the professors who are condemned to help in carrying it out. The whole system is foolishness from top to bottom, and the men prepared by the system cannot see how abominable it is, even when they are afterwards trying to improve it; well mannered mediocrity is everywhere successful and reproduces itself.

I have been dwelling upon the consequences of letting aristocratic University men who are to be rulers of the country have an education which involves no study of natural science. Besides these men we have a larger number of middle-class men who will succeed their fathers in the management, not merely of landed estates, but of much more valuable estates in the manufacture and distribution of things. With them there is the same contempt for books, for learning, and the same absence, not merely of knowledge and of natural science, but of those scientific habits of thought and methods of approaching problems which experimental research tends to produce. These men become the owners of factories the spirit of which ought to be scientific research; the competing factories in Germany, France, and America are run by men of scientific method, but our owners discourage reform in every possible way. The rule of thumb of their fathers and grandfathers is good enough for them. Their factories are so badly arranged that the works cost of any manufacture is twice what it ought to be and the time taken is twice as great. They take eagerly to all sorts of quack remedies for bad trade; they are the easy victims of fraudulent persons. These are the men who discourage all education in the people employed by them, managers, foremen, and workmen. They are what I call unskilled workmen—that is, unskilled owners of works—and it is the University and the whole system of their education which is to blame for their unskilfulness. It is astounding how quickly unskilled owners of works are being eliminated, but there is a new crop of them every year. The want of education of these men is very harmful to the country.

But I get too angry when I think of what our Universities might do in the great world of natural science and of the futility of almost all their studies. And this anger is greater when I think that the Universities rule the schools. The general higher education of the community is being altogether neglected, the general culture of professional men is being neglected; and in the case of professions involving applications of physical science, useless obligatory subjects are insisted upon, so that for these professions the University is a harmful institution. Medical students have so much hard work in various kinds of grammar subjects required for matriculation that they must be forgiven for their utter ignorance of natural science. But an outside Philistine may also be forgiven when he suggests that the whole country might benefit if the school training of medical students put them more in sympathy with scientific discovery. It is a

well known fact that there are medical men in lucrative practice, said to have the highest University qualifications, who tell you frankly that they do not believe in bacteriology!

A great many young men from the secondary schools are now entering the engineering profession. By engineering I mean any kind of applied physical science. Every important town in Great Britain has established at least one great technical college at large cost in building and apparatus, with staffs of professors and teachers (always badly paid), and it is found that for their first two years the students have to be kept at great cost to the country learning those simple principles of science which they ought to have learnt at school. It is found that they are not only ignorant, but they have none of the habits of thought and scientific method which school laboratory work induces. The clever ones, if they leave school at seventeen, recover from the effects of a school education which prepared men only for being lawyers or clergymen; but the average man finds that he has been prepared only to be a hewer of wood and a drawer of water to the real engineer. It is found in most cases that the successful students are those who have attended primary schools where no boy is compelled to learn any language other than English, and where every boy does laboratory work in mathematics and natural science. There can be no doubt that poor boys have now an enormous advantage over the sons of rich men, for even when the fees of the day classes are large the evening class fees are small, and the poor boys attending the latter are getting to be very fit for higher study in natural science.

The English school system has outlived the mediæval conditions which produced it. In old days the only way to knowledge was through Latin: all writing was in Latin. The result then was pretty much what it is now; lawyers, clergymen, and schoolmasters had to know some Latin after school life; the average man forgot anything he had learnt. A few very clever men did read, but the average monk or priest was a very ignorant person.

English people know the worthlessness of the public school system in the mental training of the average boy. Why, then, do they submit to it? However conservative they may be, they would not submit to this worthless system merely because it is hallowed by a history of 500 years.

The fact is, this worthless system continues because in some occult way it seems to have a connection with something of real importance, *public school form.* There is really no connection. When, in my youth, I was a master at one of the great English public schools, like everybody else I was a frightful prig in regard to public school *form.* Eton form or Harrow form or Rugby form or Clifton form was the thing at each of these schools which was thought to be of more value than anything else in the world. Dr. Arnold, of Rugby, taught the trick of manufacturing it. It is in itself a splendid thing. The public school boy is trained in self-possession, modesty, cleanliness, truthfulness, and courage. At school his health in body and morals is all important. He learns to lead and also to obey. But the average resulting man is exceedingly ignorant; he neither reads nor writes, and he has little reasoning power except what his sports have developed. This form is essentially aristocratic. It is based on superiority of position or birth or caste. A man's place is fixed, his attitude to people of higher or lower rank is fixed. He needs no self-assertion, and he cannot become a 'bounder,' that is, a 'cad'; but in Thackeray's sense he is usually a 'snob,' and in various directions he may be a *prig.* By prig, I mean a man who cannot get outside convention and so cannot exercise his own common sense. One defect is that public school form when combined with poverty cannot make much money by its own ability, and if it does not starve it must join the valets or the grooms. Its strength lies in convention and habit and the belief that poor people are not men but a lower kind of animal who may be pitied as we pity a suffering dog. Such pity can never raise the people or reform abuses. In the middle ages young gentlemen of England had the same sort of education. It was probably best in Plantagenet times, when indeed a well trained young gentleman was not only very healthy and courageous, but he had not much chance of becoming lazy. A man was proud of his heavy armour, and he was trained to act vigorously when carrying it. They were chivalrous to each other, but, alas! to people outside their own class they

were cruel. The Black Prince is typical; think of his courtesy to King John of France, and then think of his destruction of the persons and property of all the peasantry in those large regions of France which he covered with his marauding soldiers. This kind of chivalry, which is never exhibited to a lower class than one's own, has its beauty, but it does not suit a democracy; it requires that there should be a lower class than its own. The Spartans needed their helots. The Southern planter in America had fine manners, but he could not have cultivated them if there had been no slaves and mean whites. It is a well-known fact that some years before the Civil War in America it was seriously proposed by prominent Southerners to make slaves of the 'mean,' that is, the poor whites. The chivalrous Andrew Fletcher of Saltoun showed but little knowledge of his countrymen when he formed his plan for reducing a large part of the working classes of Scotland to slavery. Public school form may sit not unhandsomely upon country gentlemen or any rich men who have many servants or tenants or other dependents, but it does not sit at all well upon poorer men, for it puts them out of sympathy with people among whom they must work. It is heartbreaking when associated with the poverty of a man looking for work in places where he has no influential friends, as it is nearly always associated with illiteracy and want of wisdom, with helplessness and with disinclination to learn. Nobody doubts that a modern country gentleman is much more polished than Squire Western or Squire Lumpkin, but he has much the same opinions and forms them in the same way. The manners of a young officer are certainly superior to those of Ensign Northerton, but he is in much the same state of ignorance.[1]

We ask the schools for mental power as of old one asked for bread, and they give us a stone. No doubt public school form is a beautiful stone, a diamond; but we want some bread as well, even if it were only in the Falstaffian proportion of bread to sack. For my part I do not see why the average boy at school should not have reasoning power and a love for reading and knowledge as well as good manners, and this is why I ask for a great reform in our schools. We want from the school what Nature has not been accustomed to give, and what home life cannot give, the development of the intellect, and the school fails to give it in ninety-five out of every 100 cases. The great danger in school life is that it may hurt individuality, originality, because a boy, however harum-scarum, is naturally conventional and imitative. Good form comes easily therefore, and the master is more than satisfied, he is proud. He often speaks of it as *character*, but he is quite wrong. Character comes from home life, not from school life, which indeed is rather antagonistic to character. It comes from contact with fathers and mothers, brothers and sisters, relations and friends. School life tends to induce a contempt for the lower classes and a slavish admiration of

[1] The Report of the Commission on the Education and Training of Officers of the Army (1902) is well worth study. Dr. Maguire, the most experienced coach, said, as a witness :—'Latin, as taught to the average schoolboy, is pure waste of time, and does not develop intelligence or tend to breadth of culture in the least or facilitate the acquisition of modern languages.' . . . 'The prominence of ancient classics in English schools and the large proportion of youthful years devoted to failure in regard to them explain the stupidity and incapacity of their pupils as compared with the same class of persons in other advanced communities.' . . . 'They [classics] are kept in such vogue to suit the convenience of languid schoolmasters who can teach nothing else, and for no other reason whatever.' He spoke of 'the absurd anachronism of lazy and costly schools, which rendered so many of us ignorant of the very subjects which are generally useful and interesting.' He said : 'but our educational system all round is utter folly at best.' Speaking of English Universities, 'the whole system is a grievous absurdity.' '"Society" and snobbery are the curses of England.'

This address was delivered in Australia when we had been at war with Germany for three weeks. It was written eight months before. I told my audience that the printed proofs which were in their hands contained statements meant only for good, which might be harmful in time of war, so I left much of it unsaid. In this page I have deleted a long paragraph concerning young English officers.

the upper classes, which is altogether wrong in a democracy, and can only lead to evil.

It always happens that the real education of the average man begins when he falls in love and sees the necessity for writing love letters. He must have spent many years of worry at school and passed examinations in Latin and mathematics, perhaps in French or German, in geography, and many other subjects, all taught in water-tight compartments, yet he is quite illiterate. If he has been slightly higher than the average boy he is able occasionally in after life to quote one or two tags from the Latin grammar and to say that he thought he remembered something of the *pons asinorum*; he is also fond of using the expression 'the unknown quantity *x*,' because it shows that he once worked at algebra. A Premier of Great Britain who had sent out a great military expedition to Cape Breton expressed great delight afterwards when he suddenly discovered that Cape Breton was an island. Chancellors of the Exchequer have shown themselves to be quite ignorant of the simplest arithmetic. A very successful Cambridge coach told me that it is quite common for the father of a pupil to tell him that he does not wish his son to get a good degree. Generalisation is always dangerous, but I think I am safe in saying that Englishmen of the higher classes do not believe in education. They believe in what they call character, which always to them means public school form, and they believe in mental mediocrity, which in most cases means mental inferiority. This gives one explanation of the persistence of the public school system. The man who remembers his years of dull school classroom routine with no intellectual result is not likely to be enthusiastic over the education of his son.

Unfortunately all secondary schools try to copy the public schools. They also aim at teaching good form, mainly by magnifying the importance of football and cricket. To differentiate themselves from the primary schools, they compel every boy to learn through Latin. And all this they do at a rate which suits the pockets of the lower middle-class parent. It is a poor imitation of a system only one part of which is worthy of imitation.

I can understand why Tom Sawyer and his friends, when they started their gang of robbers, initiated them through passwords and a ritual. That was for 'side.' The gang did not consist of pirates or robbers; they were innocent young boys, and their passwords and ritual were the essence of the romance of the thing. Latin for the average youth seems to me to be merely grown-up Tom Sawyerism, and is allied in obvious ways to the worship of Mumbo-Jumbo. It used to be that the use of fur on clothes was reserved for the higher classes. At another time gentlemen only were allowed to wear swords. In China and Japan certain buttons and coloured dresses indicated certain rank. In our own time there are fashions of slang which distinguish the smart set of society. The survival of Latin and Greek is very much the same sort of thing. It has no more to do with education than the two hind buttons of our coats or the wigs of our judges have to do with convenience. The classics ride us like Sindbad's old man of the sea. All over the British Empire a well-educated man cannot become a professional man of almost any kind unless he pretends to know something of one or more dead languages, such knowledge being of no essential value to him. It is something like what the old Test Act imposed upon us; for 130 years a British citizen perfectly competent to fill the highest posts could not take upon himself the smallest kind of public work unless he could swear to a certain formula. Most of the numerous students of a very important School of Mines refuse to take their B.Sc. degrees because they are wise enough to refuse to learn Latin. The mine-owners are wise enough to engage these men if they possess only the college diploma, although they have no degree. There is hardly one mining engineer holding a University degree in the country that I speak of. Indeed, I may say that only a few mining engineers in Great Britain hold a University degree, and this is for the same reason.

If there is any particularly useless, poor, genteel clerk you will find that his son must be taught Latin. If there is any little township in a new country where everybody is ignorant, the schoolmaster must teach Latin. Any cheap schoolmaster, knowing nothing, worth nothing, will, you may be sure, say that he can teach Latin. If there is a particularly illiterate bar-room loafer in the town who never reads books or newspapers you will find that he has a stock-in-trade of perhaps three Latin phrases which keep him provided in beer.

Do you know why Portia the Maid of Belmont remained so long unmarried? It was because her suitors assumed that the golden language of conquest was Greek and the silver language was Latin. If you read between the lines you will see that this is what Shakespeare meant. His leaden casket signified the English of Belmont-cum-Stratford-on-Avon.

The worst of it is that the average boy who has done almost nothing else than Latin and Greek at school gets absolutely no love for the classics; he never reads a Greek or Latin author after he leaves school. He might enjoy them in translations, but he hates their names, and even if he did not it would never enter his head to read a 'crib.' Surely this is the natural effect of the schoolroom routine.

Following that article in *The Times* newspaper, referred to above, in a discussion, the secretary of the Association for Improving the Teaching of Latin said, 'Out of the vast number of boys who learned Latin only a few reached the stage when they could read the classics with any pleasure. A still smaller minority continued their classics after they had left school or the University. The great majority left school with very little, if anything, as the result of years spent in the study of the classics.' The next speaker said that the reforms suggested 'were based upon the assumption that the present method of classical education was wholly bad. He did not agree.' Nor do I agree. I think that if there is one subject that the ordinary public schoolmaster can teach it is Latin. I take the first statement as right, however. I have always said so, loudly, to an unbelieving world that thought me prejudiced, and here we see a lover of the classics inadvertently supporting me, and surely every fair-minded schoolmaster must agree with him, at all events as concerning the average boy. It is not the method of teaching that is wrong; it is merely that Latin as a school subject for the average boy must be altogether condemned. It takes from him all interest in every kind of literature; it makes him dislike reading. We must have some compulsory subjects, and I think that any boy may be taught any subject—to some extent; but we ought to have as few of these compulsory subjects as possible, because any subject may be found very difficult by certain classes of intelligent minds. And it is surely ludicrous when a clever mathematician, well read in Natural Science and fond of English literature, is plucked for his degree because of his poor Latin or Greek. I knew a case where the first classic of his year would have failed to pass his 'Little-go' only that special arrangements were made to let him through his mathematics easily. My own career was nearly ruined because I failed in a French examination.

Before a student enters a University he has to pass a Matriculation examination, so that we may be sure that he is fit to follow any of the courses of study. In mediæval times the one compulsory subject was Latin, because all the literature known to students and teachers was in Latin, all lectures were delivered in Latin, all teaching was in Latin. Consequently in some Oxford Colleges a man was fined if he spoke in any other tongue. Then came the time when there was still no English literature, and not only was the best literature in Greek, but Greek was the only approach to natural knowledge, so Greek also was compulsory, and so it has remained to this day—to this day when English literature (including translations) is of greater worth than any ancient or, indeed, any other modern literature; when all teaching, all lectures are given in English, and when our English knowledge of Natural Science is not only infinitely greater than anything possessed by the ancients; but it enables us to say that the ancients were hopelessly wrong; when nobody but the official University orator or some traveller ignorant of the language of a foreign country speaks Latin and then speaks rather the language of Stratford-atte-Bow than the Latin of the City of the Golden Shields. The men of the City of the Violet Crown were not handicapped by being compelled to learn any other language than their own, to waste their time on mere words; 'they were engaged in pursuits of a higher nature, in acquiring a knowledge of *things*. They did not, like us, spend seven or ten years of scholastic labour in making a general acquaintance with two dead languages. These years were employed in the study of *nature* and in gaining the elements of philosophical knowledge from her original economy and laws.' The above quotation is from the Langhornes' 'Life of Plutarch,' and it is particularly valuable as expressing the views of two great classical scholars.

I would make a knowledge of Latin or of Greek compulsory only on students

of certain subjects, and the professor ought to impose the condition, not the University. Again, students of certain other subjects ought to know one or more foreign languages, and, indeed, it seems to me that the professor in each subject has a right to insist on his students having certain special knowledge before they enter upon a study with him. But to enter the University, surely the compulsory subjects ought to be as few as possible. It seems to me that the most important thing is to make sure that every student has had an early education through his own language—English; that he should be able to write an account in English of anything he has seen; should have some acquaintance with what are called English subjects, such as geography and history, and the principles of natural science, and the power to make simple computations. All the teaching is to be in English, all his companions speak English; there are good English books on all subjects, there are English translations of all the good books that have been written in foreign languages. So abominable do I think *compulsory* Latin or Greek or French or German that I believe a primary school to be a much better school than any other for a boy if he is fitting himself for any profession in which applied science is important. At present English is not taught properly in any British school. The teachers are all classical men, who are very careful when they write Greek or Latin and exceedingly careless and slipshod when they write English. We might easily write a fairy story about three sisters —Greek, Latin, and English—and call it 'Cinderella.' The language of the greatest empire known in history, the empire of the English-speaking peoples, is not taught seriously in any part of that great empire. It is shocking to get from a great classical scholar a letter with misspelt words on every page, every sentence being ungrammatical. When will our good modern writers tell us how English composition may be taught to ordinary folk?

I want you to understand that we have established some fundamental principles in our science: (1) A subject must interest a pupil. (2) A man who trains dogs or seals or bears or other animals makes a close study of their minds. In the same way we must recognise that one boy differs from another, and study the mind of each boy. (3) If a boy is not very receptive of an important subject we must do our best with him and try to settle what is the minimum with which we ought to be satisfied. Only a few subjects ought to be compulsory on all boys. (4) There are two classes of boys unequal as to numbers, (*a*) those fond of, and (*b*) those not capable of, abstract reasoning. (5) Another two classes are (*a*) those fond of, and (*b*) those not fond of, language study. (6) Every boy may be made to write and read in his own language and he may be made fond of reading. (7) The average boy's reasoning faculties are most surely developed by letting him do things. That is, for example, through his sports, or through wood or metal working, or gardening, or experiments involving weighing and measuring. Through the last of these he learns to compute. A boy of eight learns decimals in an hour if he weighs and measures, whereas by the usual method of teaching he is ignorant of decimals at the age of fourteen. A boy learns whist very quickly if you seat him with three other people at a table with a pack of cards; he would not learn in a month if he had no cards. Would you teach a boy to swim by mere talk? (8) Every boy must get a good deal of personal attention. (9) However good a system may be there can be no good results if the teachers are cheap; cheap teachers are usually stupid and overworked. Men in charge of schools and colleges never seem to learn this. The market price must be paid for a capable man. (10) Fairly good results may be expected from a good teacher, even when he is compelled to work on a bad system, but really good results can be obtainable only from a good teacher with a good system.

I need not go into details about all these principles, but I should like to dwell presently upon a few of them. At the beginning of this Address I spoke of the obstruction to great necessary reform—too much antiquated machinery to 'scrap.' Most schoolmasters will admit the necessity for reform in the case of the average boy, but they say that parents are opposed to the reform. Unbelief in education for the average man is so general among the higher classes that I am afraid we shall have no reform unless some great national disaster causes conversion. There is a lesson for England, and, indeed, for all European races, in the recent history of Japan. The old structure of Japan was in many ways beautiful, but it proved to be without physical strength. Its extreme weakness

proved its salvation. Even the teachers of ancient classics saw that for strength it was necessary to let scientific method permeate the thought of the whole population. And now, at the end of the first chapter of Japan's modern history, we find a nation which can not only defend itself, but which retains all of its spiritual life which was beautiful. Every unit of the population can not only read and write, but it is fond of reading, and its education did not cease when it left school. It is getting an increased love for Natural Science, so that it can reason clearly; it is not carried away by charlatans; it retains its individuality. One result of this is that in time of war Japan has scientific armies. Not only are its admirals and generals scientific, but also every officer, every private is scientific. Everything in the whole country is being developed scientifically, and we Europeans, hag-ridden by pedantry in our schools and universities, refuse to learn an easy lesson. At present we do not even ask what is meant by education or what education is necessary if a particular boy is to be fitted for his life's work. In 1902, when I was President of Section G, and in opening a discussion on the teaching of mechanics at Johannesburg in 1905, I gave my views as to the teaching of a young engineer, but they apply also to the teaching of nearly all boys. These views have been commended by experienced engineers and teachers. To understand me it is first necessary to try to cast away prejudices, and this is especially difficult if one has a pecuniary interest in education. The student of almost any other science than education cares for nothing but the truth; even when he has committed himself to a theory and his good name or credit is at stake the rule of the game is perfectly well known and must be adhered to. The student must not neglect fact or pervert fact; he must be quite fair. The student of physical science sees at once whether or not he is playing the game, because the co-ordinates are few; there are no complexities, such as we find in our own life problems. This also is why the study of physical science is so good in causing boys to reason, for reasoning can only be taught by constant practice on simple matters which one thoroughly comprehends. Consider a boy's views about ordinary affairs. He is downright. A complex thing must be greatly simplified to him. His painting is in black-and-white; there is no delicate shading in his picture. He never sits on the fence; he is never a trimmer. An historical character is awfully good or awfully bad, very clever or very stupid. A boy is, in fact, cocksure about everything. He is incapable of reasoning about complex things. And when we try to teach him to reason about simple things we must be quite sure that they really are simple to him, that he understands them. For example, many educationists say that the study of geometry is just right for a boy. Well, yes, for five per cent. of all boys, boys who can take in abstract ideas. They take to Euclid as a duck takes to water. But for the other ninety-five per cent. geometry is very hurtful, because unless they continually experiment with rulers and compasses they do not understand what the reasoning is about. In ancient times only very old and exceptionally clever men were allowed to study geometry. We now assume that it ought to be an easy study for the average English boy. Generation after generation we stupefy the average English boy with demonstrative geometry, and we call him a duffer so often that he thinks himself a duffer, and even his mother thinks him a duffer, and, indeed, we have done our best with geometry and Latin to make him a duffer. Only for his football and cricket, which teach him to reason a little, he would become a duffer. And yet in my opinion if this average boy were properly taught in school he would prove to be very superior to the boy who is usually called clever The schoolmaster calls a boy clever because he is exactly like what the schoolmaster himself was when a boy; but I am afraid that I place little value on the schoolmaster's cleverness, whether as a boy or a man. Reasoning can be taught through almost anything that a boy does, but more than all things through his experiments in Natural Science. Formal lessons on reasoning, on logic, are utterly useless, and I may say that set lessons on almost any subject are utterly useless for the average boy.

Milton's poems are greatly praised. Well, I am not going to say a word against the people who talk in public about the most wonderful epic in our language and who never read it; but how many people have read Milton's magnificent prose works? Milton first taught me the true notion of education, that the greatest mistake is in teaching subjects in watertight compartments. It is the idea underlying one of the most instructive books ever

written, 'Sandford and Merton.' When teaching a subject, teach all sorts of other subjects as well. If Mr. Barlow's boys were interested in astronomy he showed them stars and planets through a telescope for a night or two, but he gave them no stupefying course on astronomy. He gave them stars and the solar system just as long as they were interested. He used a globe as well as mere maps in teaching them geography and history, but the soul-destroying idea of a course of study on 'the use of the globes' did not commend itself to him. They walked over the fields and took an interest in trees and flowers, but he gave them no stupefying course on botany. When he gave them a lesson on English grammar or literature he taught them at the same time the geography and history and the fairy stories of their country. How can a man give a course on grammar or geography or history or anything else without diverting his talk in an interesting way to other subjects? What is so tremendously important about Natural Science laboratory work is that a student must be thinking all the time about the same matters, not from one but from ten interesting points of view. He is not merely observing, he is measuring, he is computing, he is reasoning; he has to write out descriptions of what he sees and does, and he thinks then of his spelling and grammar; he has to sketch; he has to read books about what other people have done before him on the same subject, and also for statistics. He learns the value of a bit of work done in a clean honest way, and when he gets some more experience he glows with the feeling that he has really added to the knowledge of the world. He is a discoverer, and he feels the emotion of Cortez! It is marvellous the alteration which has occurred in the mental attitude of the common average boy. Instead of feeling that he is a degraded slave he feels the emotion of his childhood returning to him. He once made the great discovery at the age of six that the back garden was inhabited by fairies and lions and Indians and pirates. He was the Caliph Haroun Alraschid for a while. And now, after a wretched life at Latin and Euclid, a new revelation is vouchsafed to him, and as he gathers years he finds that Nature is placidly willing to let him steal her secrets little by little, one by one, secrets that are gradually changing men from the bewilderment and spirit possession of the Middle Ages; so that at length he enters into complete communion with Nature and rollicks with her, and quarrels with her, and loves her more and more until he dies. And his reasoning power has been growing all the time, so that more and more he understands complex things, for, after an experimental study of story-books, he probably entered the kingdom of Shakespeare at the age of fourteen. Things requiring memory can be learnt only in early life—weights and measures, the multiplication table, languages. He knows games involving spelling. But, over and above all these, he has from infancy repeated all sorts of poetry long before he could enjoy much more of it than the jingle of its rhyme.

Education consists in the development of a man from his earliest day, and does not cease till he dies. Any thoughtful man must see that there is no science so important as that of education, the preparation of children of this generation to be the citizens, the rulers of the country, in the next generation. The whole future of our Empire depends upon the education of the children. By the study of this science we hope to improve teaching so as to make future citizens not only to have more knowledge and more skill, but to make them wiser than the people of the present or the past.

Early training determines what later training ought to be. Let us consider what the early training of a boy ought to be. In his very early days Nature has provided that his education shall proceed very rapidly by observation and experiment, and the only teaching needed is through careful nursing and affection. He teaches himself, and he loves to learn. He ought to get toys not too realistic, for he loves to weave romance round his toys, but still things to observe and experiment with. He has most complex problems in physical science when he is only a few weeks old, the solution of which involves much labour, but it is pleasant labour and he is happy. And he will remain sweet-tempered and happy and unspoilt if there is real affection from his teachers. If, however, somebody teases him by playing practical jokes, or if a selfish mother who was unreasonably kind to him yesterday is unreasonably unkind to him to-day, he gets, because of his reasoning power, a sense of injustice. Man, woman, or child with a sense of injustice may be said to be possessed of a devil. During the first six years of a

child's life the creation of its power to reason is more wonderful than anything else, and this reasoning power comes altogether by observation and experiment. An affectionate parent easily finds methods of helping Nature in this process. The unspoilt boy of six years seems to forget nothing that he hears; he has gathered a most wonderful vocabulary; he knows endless nursery rhymes and simple poetry; he is as active and adventurous as a kitten, and everything he does is cultivating his senses. This is the time when he fills the smallest playground (which to grown-ups seems bare and desolate) with giants and fairies and Indians and pirates, with forests and mountains and rivers and oceans. His imagination is so extraordinary that the most uncouth creation of his own gives him exquisite pleasure. Why do I dwell upon this stage of a boy's development? Because it has been so perfect! Nature has learnt to do this to children during perhaps hundreds of thousands of years, and it has been the most important time of a boy's life, the time when, if parents will only give the boy their love and greatly let him alone otherwise, he develops mentally more than during all the rest of his life. Speaking broadly, he has done nothing in all this time except what Nature and affection made pleasant to him. I have studied the science of education and practised the art of teaching all my life, and I say that all our failures are due to our neglect of Nature's methods, and our schools destroy the good effects which Nature has produced.

As a rule I do not like to be told that certain subjects must be compulsory, but surely every child of eleven must have some such qualifications as these: (1) The power to speak and read and write in his own language. (2) To be able to do easy computation. (3) To have an exact knowledge of the simplest principles of Natural Science from his own observation and experiment. I think that every observer must acknowledge that these powers are possible for almost every boy of eleven. Some of us have for many years been endeavouring to show how the child of six may acquire these powers by the age of eleven if Nature's methods—that is, Kindergarten methods—are followed. For example, he plays at keeping shop, selling or buying things by weight and measure, and paying or receiving actual money and giving change. He weighs and measures with greater and greater accuracy as he makes experiments in mechanics and heat and chemistry. Every boy is fond of stories, and if treated reasonably is easily induced to learn to read. Reading aloud is easily made a pleasure and a habit, and so the boy learns to speak properly. Any boy whatever will become fond of reading if the people about him are fond of reading: I state this as a fact which I have investigated. A boy who is fond of reading gets later on to know the value of books and the use of books, and he will go on educating himself till he dies. Any attempt at coercion, unless it is the very gentle coercion of a person whom he loves, is fatal; even coaxing is not always good. He assimilates knowledge from everything which he does, and therefore he ought to be induced to do things which not only keep him healthy, but which give him knowledge and teach him to reason. Do you remember how angry Lanfranc of Bec was at the idea that any pupil could be *forced* to learn; he said 'it turned men into beasts.' I speak to you who love children, who love young people, who know that there is hardly one child in a hundred, even among rather spoilt children, who does not love to do his duty.

Under the best and most loving of teachers a lonely child has enormous disadvantages, but these can generally be remedied. The usual mistake is to send it to a large school. If it is merely a day school there is no great harm. But no child under thirteen ought to be sent to a boarding school unless it is a small school and the master and his wife have a love and sympathy for other people's children. There are such people in the world, God bless them! but they are not numerous. They are so few that we must return to Nature as the best of teachers. The time is coming when a child's own father and mother will have much more knowledge and wisdom than they have now, and they will refuse to give up to others the doing of their highest duties. It is at present not sufficiently recognised that the most important duty of the parents is the education of their children. At present, men who are building up fortunes are too busy to think of their children, and so we find that the sons of Lord Chancellors and other successful men have been marrying chorus girls and squandering those very fortunes to which their education was sacrificed. Of course, if parents are uneducated, and therefore selfish or otherwise foolish, any kind of school may be better than home for their doomed children. It is one of the great advantages of poverty that the

children go to day schools and they keep in touch with home life. If the day school is really a boarding school as well, it will be found that there is always a differentiation in favour of the boarder, which has a very bad caste effect, just as the 'modern-side' boy of any public school suffers in character because he is of a lower caste than the classical-side boy. It is usual to remove a stupid classical-side boy to the modern side, and every boy on the modern side has a sense of injustice. The work of the modern side ought to be much the higher, but it is always badly done because the atmosphere is altogether bad.

It may be said that I am only destructive in my criticism of public schools. I think it will be found that I am also constructive, although I acknowledge that my sketch needs much filling in. Well, can much more be done in an address lasting one hour? I will now try my hand at a little filling in. I have no objection to the existence of classical schools something like the present for boys who are fond of classics. The average boy will not be asked to attend such a school. I feel sure that much greater attention ought to be paid to the teaching of English composition, to English poetry and prose, and to English subjects generally. I also feel sure that much attention ought to be paid to Natural Science. And surely it can do no good for the classical masters to go on sneering at Natural Science subjects and calling them 'stinks' as they do now.

I want, however, to speak more particularly of a much higher kind of school, which will educate the boy usually called clever and also the boy usually called stupid. As I have already remarked, I think that these names may sometimes be redistributed.

The school is one for boys from eleven to sixteen years of age. It ought in no way to be connected with any classical school. English subjects will predominate, but teaching in Latin and Greek and modern languages and other alternative subjects will be provided, although they will not be forced upon any boy. The masters who teach English ought to know enough Latin and Greek and Celtic and Old English and modern languages to be able to illustrate the derivation of English words through their roots. And they must be well read in English subjects and fond of English literature. They will make the boys fond of reading English, and encourage them to find out what they like best. Some boys will take to history and philosophy, some to poetry and imaginative literature. Every boy ought to get the best chance of developing his faculties. It may be asked—if we cannot make the average boy spend or waste twelve hours a week on Latin, what are we to do with him? At all events, now, we keep him doing something, even if it is only marking time. My answer is, you think only of his putting in time; well, then, let him put in his time at work that interests him; any work of that kind must be educative under an intelligent master who can help him in his studies if it induces him to look up information for himself. Thus, when reading travels or history, he will use the globe and raised maps and read geography, and hunt up plans of battlefields. Think of the things that a boy used to be punished for doing, and let him do those things under wise direction. I used to be punished for reading Scott and Cooper. Nowadays prizes are given to boys for their knowledge of Ivanhoe or Quentin Durward. Expand this into a system. A boy who loves to browse over Chambers's English Literature ought to be guided in his browsing, and induced to take up something more than selections, and he may easily be induced to get off selections by heart if his teacher does not show his contempt by speaking of such exercises as *Rep.* [repetition].

Let the teacher take a leaf out of our methods of teaching chemistry and physics. It has been shown that twenty-five boys doing work in the laboratory during a lesson of an hour and a half or two hours can be managed by one teacher. Experimental lectures in a lecture room have now been greatly discarded; such lessons as I speak of take place in the laboratory, but reliance is placed particularly upon the personal attention of the teacher being given to each group of students in charge of an investigation, the group not being usually greater than four in number, and often being less than two. These students are sometimes merely verifying or testing a statement made by the teacher or found in a book, but they are often finding out things for themselves. One idea underlying the work is that there ought to be more and more illustrations of simple fundamental principles. It is long before these simple things really become part of a boy's mental machinery; things like the mere definition of *force*, for example. It is, of course, quite different work for the teacher from anything that he used

to have to do; for one thing, being much more exhausting. He cannot shirk his duties and sit down waiting for students to come to him. When teaching degenerates into mere maintenance of discipline, everything being regarded as right if the pupils are quiet and seem to be diligent, it is necessary to make a radical change, usually a dismissal of the teacher. It used to be that a science master gave an experimental lecture, and afterwards he had a very easy time, letting the students follow a set routine in the laboratory, but this will no longer do; such attendance at lectures and laboratory work means poor mental training.

Now, I would work out a system for English, English composition, English poetry and prose, geography, history, and other English subjects, on the lines that we have found so successful in Natural Science. An enormous change has been effected during the last fifteen years in the teaching of mathematics. The older methods always failed with the average boy or man. The new system, which is sometimes called *Practical* Mathematics, is based on the idea that students shall work experimentally, just as they do in their Natural Science. It is found that their eyes and faces are bright, they work hard, and they evidently enjoy their work. We have merely introduced common sense into the teaching; we have approached the student's mind from other points of view than the old academic one, from the only side on which he has ever been taught anything—the side of observation and trial. He weighs and measures. He does experimental geometry and mensuration, and is assisted by abstract reasoning just to the extent which interests him; he makes plans of the school buildings and maps of the district; algebra becomes interesting when in co-ordination with experiments in mechanics and physics; trigonometry becomes interesting in the actual measurements of heights and distances. The infinitesimal calculus is bound to be a weapon which any boy of fifteen easily gets to understand by actual use when he is dealing with dynamic experiments. In fact, the physical and mathematical laboratories are in one, and the same teacher takes charge of both subjects and teaches them as much as possible together.

Furthermore, in the preparation of an account of an investigation there are practical lessons in English composition; there is sketching, and also more careful drawing with instruments, and the finding of empirical laws, using squared paper. In such a school every subject is being taught through all the other subjects; every boy is doing the work in which he is greatly interested, and no boy is attending merely and putting in time. Furthermore, out of school-time there might be the usual restrictions as to 'bounds,' but otherwise I would let a boy do pretty much as he pleased. 'Prep.' at boarding schools and home lessons for boys at day schools are to be quite discredited. I would—it may cost a little more money—allow a boy to work in the workshops or laboratories or library or in his own room or common rooms at anything he pleases in this off-time, and I would give him advice only if he asks for it. If I saw a boy reading a penny dreadful I would not stop him; nor if he were reading Paine's 'Age of Reason,' or any wretched treatise on psychology or logic. I would in no way discourage a boy from acquiring a greater and greater fondness for reading, knowing that this is the foundation of future happiness and education, and that no harm which he can get from his reading is of the slightest importance in comparison with the importance of our main object. As he grows up he will become less and less fond of the sixpenny magazine. The school can at its best be merely a preparation for the lifelong education of the man. I would not keep the boy at school after sixteen. Let him then go into business, or to a science or technical school, or to the University.

Unfortunately for the present no University will take men without an entrance examination involving other languages than English. This is a great evil, but it is not going to last much longer. In the meantime a competent coach will prepare any student to pass the necessary examinations (say, in Latin and Greek) in three months, even if there is much other work to do. This is not a matter of learning any classics; it is rather the manufacture of some contempt for the classics, a necessary evil for the present. Indeed, for the present, but let us hope not for long, there are many other necessary evils. We have to find competent enthusiastic teachers, we have to persuade governing bodies to pay salaries two or more times as great as at present, we have to make parents see that some mental training and fondness for reading and writing are really of value, and that Tom Sawyerism about Latin is only childish.

The importance of primary education is now well recognised. Rich and aristocratic folk know that they are now in the hands of the common people in a democratic country, and it is important to see that the common people shall be made fit to rule and shall have a real sense of fairness and reasonableness. Above all, if they are to be good citizens we must cultivate their common sense. I think that in the schemes and the administration of primary education by the Boards of England and Scotland it is in a good way; but there is one great curse upon it, and the enormous sums of money spent upon it are greatly wasted. The local authorities give to every teacher far too much to do, and they give him only half his proper wages. In a few years the Government of our democratic country will be in the hands of the boys now at school. That they should be good citizens full of common sense is more important than any other thing. If they are without fondness for books, and if they cannot reason, their votes will be at the command of fraudulent or foolish, or perhaps only selfish or self-deceiving speakers. Our empire was ruled by George the Third, and by God's grace we only lost America and piled up the National Debt; but think of an empire ruled by millions of Georges! Teaching the young requires great wisdom and sympathy, and we entrust it to people paid half wages, the 'otherwise unemployed.' In the secondary schools also we find this penny wise pound foolish policy, and it is particularly evil in the great technical schools. A city is proud of its magnificent college of science, first because of its architecture; secondly because of its equipment in apparatus, perhaps in steam and gas engines and other expensive machinery. And the man in charge of the most important department of that college receives perhaps 250*l*. a year. He ought to get at least 600*l*. That is the market price of a fit man, and without a fit man the whole money and the time of students are being wasted; the thing is really a fraud, a whited sepulchre, and of course the Principal is always a classical non-scientific man. Photographs of the building and its laboratories are very fine to look at in guide-books of the city, and the managers of the college get public thanks for their services. I know nearly all the technical and science colleges of Great Britain, and I hardly ever see any of their complacent managers, members of their governing bodies, without wishing that I had some of the powers of the familiars of the old Spanish Inquisition. What right have they to undertake duties which require a knowledge of Natural Science?

The latest proposal of our callous copiers of the Germans is to make attendance at evening classes compulsory up to the age of seventeen. At present working boys attend evening classes voluntarily, although in many cases they are too tired to learn much. Yet many of them do learn. These boys are almost martyrs. They sacrifice so many of their poor pleasures, and indeed duties, that they certainly deserve success in life. But it is not fair to impose these sacrifices upon boys who are, as apprentices, learning the principles underlying their trade, and who are paid only small wages on the understanding that their masters teach these principles. In 1889 I introduced a Bill into the Kensington Parliament compelling employers to provide such instruction during the working hours. Reforms of all kinds proceed with exasperating slowness, but already many employers are carrying out this idea.

In some things we reformers have made way. It is now recognised almost everywhere that examinations ought to be conducted mainly by the teachers of a student. I have often put the matter in this way: Huxley used to teach about forty students in biology; we cannot imagine better teaching. But if those students had only wanted to pass the examination of London University it is quite certain that they would have done very much better by attending the class of a cheap crammer. A University consisting of two, three, or more federated colleges is very little better than a mere outside examining body, and this is what London University has always been. I am glad that a change towards something better is now about to take place. A number of separate Universities would be better, but in two years or less, probably, the colleges of London will conduct their own intermediate and degree examinations. One result will be that when a man gets his degree he will not shut up his books for ever.

I would, however, point out that old London University, which was a mere examining body, served an exceedingly important purpose. This statement may

seem curious coming from a person who has always railed at London University as a mere examining board. I still say that it was never a University at all in the past. But a man reading hard by himself, perhaps far away from a college, could have a severe test applied to his acquirements which encouraged him in his studies when he had no other encouragement, and the test was very rightly a severe test. To do away with its outside examinations altogether, as I believe is the intention of the authorities, will be exceedingly harmful. It would be impertinent in me to make a suggestion as to the distinction which might be made between a degree conferred by his own professors upon a man who has attended regularly a college of repute, and a degree conferred by a mere examining body upon an outside student. For the first, the examination test may be easy. The Oxford and Cambridge pass degree examinations are quite easy, and rightly so, for the real qualification is that an undergraduate shall have lived for three years in the intellectual and cultured life of an Oxford or Cambridge college. In the other case the mere examination is the only test, and it is rightly very severe. The two kinds of degree differ altogether in quality. In a new country of great distances I can imagine many good secondary schools to be established having neither sufficient funds nor sufficient pupils to be qualified as Universities. Yet it may be of enormous importance that a few of the older pupils at such schools should as external students be examined for degrees by distant Universities, which, in such a case, are merely outside examining bodies. I can see the gradual increase in importance of such secondary schools leading to the establishment of something higher—namely, colleges of University rank—and I can see such affiliated colleges becoming Universities themselves perhaps after a period in which two or more of them federated themselves as Universities. But I say that there ought always to be some examination machinery by which a student who is too poor or who through any other circumstance is unable to attend a University college may be encouraged to study by himself, by having his attainments tested.

In this Address I have said nothing about the education of women. I have always advocated higher education for girls, but it is surely wicked to teach girls as if they were boys. Men are concentrative, and they specialise; women observe more and more about many things, and they really have more capacity for acquiring mental power. Until quite recently girls were saved from stupidity, but the high schools are now giving a crammed knowledge of facts and of the opinions of the tribe, so that girls and women are ceasing to think for themselves. The education of men is in a bad way, but that of women is becoming much worse.

I think that in this Address I have put forward no idea that I have not already published time after time in the last thirty-five years. I put these views forward again because, after much thought and much experience, I still think them to be correct, and I feel sure that they must prevail. But I must confess that it is only a very hopeful man who can peg away at a thankless task as Dr. Armstrong and I have been doing so long.

MELBOURNE.

FRIDAY, AUGUST 14.

Professor H. E. ARMSTRONG, F.R.S., *Vice-President*, delivered the following Address :—

The Place of Wisdom (Science) in the State and in Education.

'So soon as men get to discuss the importance of a thing, they do infallibly set about arranging it, facilitating it, forwarding it and rest not till in some approximate degree they have accomplished it.'—CARLYLE.

THIS, doubtless, is a true statement; the difficulty is, however, to persuade men of the importance of a thing. We come to persuade you. As an Association we are now eighty-four years old: our main purpose has been to obtain a

more general attention to the objects of Science and a removal of any disadvantages of a public kind which impede its progress—let me also add, its application to culture and to the public service.

By holding meetings, year after year, in the principal towns of the British Isles, the Association has at least brought under notice the fact that Science is a reality, in so far as this can be testified to by several hundreds of its votaries meeting together each year to consider seriously and discuss the progress of the various departments. On the whole, dilettanti have had little share in our debates. The Association has already carried the flag of Knowledge outside our islands, thrice to Canada and once to South Africa; now, at last, we make this great pilgrimage to your Australian shores: still we are at home. What message do we bring with us?

In 1847, when this city was but an insignificant town, it was visited by an Englishman who subsequently became eminent not only in Science but also as a literary man—Thomas Henry Huxley; he was then surgeon on board the surveying ship 'Rattlesnake.' In 1848 Huxley visited Sydney and there met the gracious lady, only recently deceased, who became his wife. In after years he achieved a great reputation on account of his services to education.

Lecturing in London in 1854, he defined Science as 'trained and organised common sense'—a definition often quoted since; none could be more apposite, though it must be remembered that 'common sense,' after all, is but an uncommon sense.

A few years later, in a public lecture at South Kensington, Huxley spoke to the following effect:—

'The whole of modern thought is steeped in Science; it has made its way into the works of our best poets and even the mere man of letters, who affects to ignore and despise Science, is unconsciously impregnated with her spirit and indebted for his best products to her methods. I believe that the greatest intellectual revolution mankind has yet seen is now slowly taking place by her agency. She is teaching the world that the ultimate court of appeal is observation and experiment and not authority; she is teaching it the value of evidence; she is creating a firm and living faith in the existence of immutable moral and physical laws perfect obedience to which is the highest possible aim of an intelligent being.

'But of all this your old stereotyped system of education takes no note. Physical Science, its methods, its problems and its difficulties, will meet the poorest boy at every turn and yet we educate him in such a manner that he shall enter the world as ignorant of the existence of the methods and facts of Science as the day he was born. The modern world is full of artillery; and we turn our children out to do battle in it equipped with the shield and sword of an ancient gladiator.

'Posterity will cry shame on us if we do not remedy this deplorable state of things. Nay, if we live twenty years longer, our own consciences will cry shame on us.'

These words were uttered in 1861. Now, after more than fifty years, not twenty merely, we still go naked and unashamed of our ignorance: seemingly, there is no conscience within us to cry shame on us. I have no hesitation in saying that, at home, at all events, whatever your state here may be, we have done but little through education to remedy the condition of public ignorance which Huxley deplored. In point of fact, he altogether underrated the power of the forces of ignorance and indifference; he failed to foresee that these were likely to grow rather than to fall into abeyance. In England, what I will venture to term the Oxford spirit still reigns supreme—the spirit of the literary class—the mediæval spirit of obscurantism, which favours a backward rather than a forward outlook.

Wherein was Huxley out in his forecast? In 1861 the claim of Science was already strong but think what has been done since that time—what we can now assert of its conquests! In the interval, even within my recollection, the whole of our ironclad fleet has been created, rifled cannon, smokeless powder and dynamite have been introduced, and this last, in combination with the discovery of the causes of yellow fever and malaria, has made the Panama

Canal possible, an entirely revolutionary work of man's interfering hands. The 'Great Eastern,' which could not be launched at first on account of her size—as a lad, I saw her sticking in the stocks—was a failure, because she was outside the fashion of her time, yet she has given rise to a host of ocean leviathans of far larger size; the steam-turbine has entered into rivalry with the reciprocating steam-engine; cold storage has revolutionised ocean transport, so that fresh food can be carried from this continent to remote England and Europe. Electricity, then a puling infant, is grown to giant size; not only have we deep-sea telegraphy and mechanical speech in the form of the phonograph and telephone, but wireless communication, the electric light, electric transmission of power, electric traction—even the waterfalls of the world are tamed through the turbine and made subservient to our will for motive purposes or in the production of temperatures bordering on those of solar heat, by means of which too we can draw food for plants, at will, from our atmosphere by combining its constituents into the form of a fertiliser. The use of oil-fuel in the internal-combustion engine has been made possible and, in a few short years, the streets of London have been cleared of horse conveyances and crowded with motor-vehicles; such engines are coming into use everywhere and enable us successfully to perform the feat which Dædalus vainly attempted—we even talk of flying from New York to London, across the vast Atlantic, to spend the week-end. The cyanide process has been introduced into gold-mining and is enabling us to unearth a fabulous wealth; a vast array of gorgeous colours has been produced and Dame Nature so outwitted that we make indigo and madder out of the tar which in old days was put only upon fences; Pasteur's work has made Listerism possible, so that nothing is now beyond the surgeon's art and bacteriology is become the handmaid of preventive medicine and sanitary science; not only paper but an artificial silk is made from wood-pulp and the finest of scents are conjured out from all but waste materials. A multitude of other discoveries of practical value might be referred to.

But there is a reverse side to the picture. At this very moment we realise with horror that whilst we have destructive forces at our disposal, unknown to pre-scientific generations, of a most terrible kind, our human nature is in no proportionate way subject to modification—nor is it likely that it ever will be—so that the desire to destroy grows less as the means grow greater. It will be my argument, indeed, throughout this Address, that Science is something apart—a cult which can influence but the few.

Not so long ago, when scientific research was spoken of, the cry was always *Cui bono?* What's the good of it all? Now, no one has the patience to listen to a recital of the benefits accruing to mankind from its operation; for all the achievements I have referred to *are not the work of mere inventors* but primarily the outcome of scientific discovery : thus our modern command of electricity is very largely traceable to the labours of the great philosopher Faraday, who worked in an ill-lighted and cramped laboratory in the Royal Institution in Albemarle Street, London, with no other object than that of contributing to the advancement of knowledge.

Perhaps the greatest of all the scientific achievements of our time remains to be mentioned—the promulgation of the doctrine of Evolution by Charles Darwin. Few perhaps can realise what this means for mankind, the intellectual advance it constitutes—that through it we have at last acquired full intellectual freedom and the belief that it rests with ourselves alone rightly to order our lives; that by it all dogmas have been undermined.

No one has stated this better than Oliver Wendell Holmes, in saying : 'If, for the Fall of Man, Science comes to substitute the Rise of Man, it means the utter disintegration of all the spiritual pessimisms which have been like a spasm in the heart and a cramp in the intellect of men for so many centuries.'

Let me say that Huxley did much to give credence to this same doctrine of Evolution : on which account Australia may well feel proud that he visited her shores and of the use that he made of his opportunity; our visit is but the logical sequence of his and we are but come to emphasise his message.

'During the last three hundred years reason has been slowly but steadily destroying Christian mythology and exposing the pretensions of supernatural revelation.'

So writes Professor Bury, the Professor of Modern History in the University of Cambridge, in his recently published 'History of Freedom of Thought,' one of the most charming historical essays ever put together. Again, he remarks :—

'If the history of civilisation has any lesson to teach, it is this : There is one supreme condition of mental and moral progress which it is completely within the power of man himself to secure and that is perfect liberty of thought and discussion. The establishment of this liberty may be considered the most valuable achievement of modern civilisation and as a condition of social progress it should be deemed fundamental.'

Science is come into being and has prospered only since freedom of thought was secured : on no other terms can it be. It is well that we should bear this in mind. The growth of numbers and of democracy may well involve a restriction of freedom in all directions—none are so intolerant as the ignorant.

If in Science, to-day, we have something unknown to former civilisations, what is its influence to be on the future of the world, in particular on the future of the white people? If we are not to suffer the rise and fall which all previous civilisations have passed through—rather let me say, *if the period of our fall is to be retarded beyond the period our forerunners enjoyed, it will be solely because we wield and use the powers Science has put into our hands* : not so much those of abstract science but the broad wisdom which the proper cultivation of Science should confer; hence it is that I desire to urge the absolute importance of giving, through Science, a place to the cultivation of wisdom in the State and therefore in education.

Clearly, two new forces are at work in the world : not Science alone but also a broad and altruistic Socialism, both the outcome of the intellectual freedom man has acquired since the deposition of the Churches. The one is gradually leading us to base our actions upon knowledge and to be practical through the use of theory; the other is leading us gradually, though slowly, to have consideration for one another, to recognise how helpless are the majority, how greatly they stand in need of the guidance of the few who are capable of leading. But we shall need to order our Socialism by Science to make it a wise Socialism. The signs are only too numerous that a wave of political despotism may come over us. Either, as time goes on, Science will be more and more of service in guiding the social machine—or that machine will perish, from the very complexity of its organisation and the inability of the units to understand their place, to understand the need of subordinating their individual inclinations to communal interests; most important of all, to understand their inability to recognise and require competent leadership—for Science is aristocratic in its tendencies : indeed, I shall claim that real Science—Wisdom—is for the very few.

The arrogance of ignorance at the present day leads too many to brush all such considerations aside. It is only too rarely that thinking men have the courage to pronounce judgment as clearly as did recently a distinguished dignitary of the Church, Dr. Inge, the Dean of St. Paul's, the cathedral of our greatest city, in a strikingly outspoken course of lectures to women. The warning he gave is worth pondering over :—

'Democracy is perhaps the silliest of all fetishes that are seriously worshipped among us. The method of counting heads, instead of breaking them, is no doubt convenient as a rough and ready test of strength : since government must rest mainly on force. It is also at least arguable that democracy is, at present, a good instrument for procuring social justice and for educating citizens in civic duty. But that is really all that anyone has a right to say in its favour. . . . There is absolutely no guarantee, in the nature of things, that the decision of the majority will be either wise or just; and what is neither wise nor just ought not to be done. This is a somewhat elementary truism to enunciate to an intelligent audience; but there stands the ridiculous fetish grinning in our faces and the whole nation burns incense before it.'

The message of Science must be to the same effect. If the Christian spirit prevail, Science and Socialism must ultimately go hand in hand—but true Socialism, not the spurious article advocated by the limited intelligence of the political intriguer of the day who leaves altogether out of account human nature

and its imperfections while preying upon the gullibility of the masses. Science is not yet a sufficiently public possession, however, to make a rational and considerate Socialism possible.

That religion will ultimately be placed upon a scientific basis—though perhaps only in far-off days—may also be anticipated, for it has been well said that in literature we already have homilies innumerable: that God's universe is a symbol of the Godlike; Immensity a Temple; Man's and Men's history a perpetual Evangel. In thus quoting Carlyle, I am aware of Mr. Balfour's ill-judged, flippant reference to his 'windy prophesyings'—that for the time being his Puritanism is out of fashion. But I prefer Huxley's estimate, who uses memorable words in saying :—

'"Sartor Resartus" led me to know that a deep sense of religion was compatible with the entire absence of theology. . . . Science and her methods gave me a resting-place independent of authority and traditions.

'The longer I live the more obvious it is to me that the most sacred act of man's life is to say and to feel "I believe such and such to be true." All the greatest rewards and all the heaviest penalties of existence cling about that act. The universe is one and the same throughout; and if the condition of my success in unravelling some little difficulty of anatomy or physiology is that I shall rigorously refuse to put faith in that which does not rest on sufficient evidence, I cannot believe that the great mysteries of existence will be laid open to me on other terms. It is no use to talk to me of analogies and probabilities. I know what I mean when I say, I believe in the law of the inverse squares and I will not rest my life and my hopes upon weaker convictions. I dare not if I would.'

. . . .

'Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before a fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abysses Nature leads or you shall learn nothing. I have only begun to learn content and peace of mind since I have resolved at all risks to do this.'

These remarkable passages occur in one of Huxley's letters to the Rev. Charles Kingsley; probably they are a fair representation of the faith that is in all whose views of life are ordered on a scientific basis. At least, they indicate our attitude towards utterances such as Sir Oliver Lodge has given expression to even from the Presidential Chair of this Association and to the fancies woven by Mr. Balfour in his recent Gifford Lectures. Sir Oliver has asserted that 'the methods of Science are not the only way, though they are our way, of arriving at the truth.' It is scarcely necessary to controvert so illogical a statement. If they are *our way*, it is because the methods of Science are the only methods known to us which we can apply in our search for truth: all methods which lead to truth are necessarily methods of science.

With all the marvellous growth of achievement to which I have referred, there has been no proportionate growth of public intelligence. Our Admiralty and to a far less extent our War Office have called Science into their service but our public Departments generally will have none of it. Even the elements of an understanding of the methods of Science are not thought to be essential to the education of a Civil Servant; such knowledge is not required even in the highest branches of the Indian Service—no politician is ever supposed to need it: we are governed almost entirely by the literary spirit.

Our newspaper press is in the hands of literary men. Even 'The Times' gives no regular place to Science—now and then chance reference is made to some discovery but too often the account is garbled. It publishes Literary and Educational Supplements in neither of which Science figures; and recently, on reducing its price in order to increase its popularity, it abandoned the weekly publication of its Engineering Supplement and issues this only monthly in an emasculated form. The Liberal press is distinguished by the infrequency of its references to scientific questions and by the superlative inaccuracy of the statements that are made. The 'Morning Post,' by reporting the meetings of societies and by opening its columns recently to a lengthy correspondence on 'Science and the State,' however, has shown sympathy with us.

The 'Daily Telegraph' alone of the Conservative papers retains the services of an eminent scientific writer but even Science cannot make a summer of one swallow. Editors who do not appreciate a subject themselves are not likely to suppose that others will care for it. Lastly, I am told by friends high up in the publishing trade that there is no demand for readable books on Science—only text-books sell and provided always that they are written on conventional lines, so that their contents can be memorised. Nevertheless, I have hopes, since Messrs. Dent have issued Faraday's 'Electro-Chemical Researches' as one of the shilling volumes in their wonderful 'Everyman' series; this is the one promising speck of white cloud on an otherwise black horizon.

The spirit of the age, in fact, is in no way scientific, though ease and comfort are now provided on an unprecedented scale through the agency of Science, the engineer acting as chief interpreter. The Churches will have none of it and almost glory in their ignorance.

Why is this? Why was Huxley so out in his forecast made in 1861? Why do we still go naked and unashamed of our ignorance of 'Science'?

One main reason is that the party in power is unscientific; but at bottom, I believe, the difficulty is a far greater one and probably innate in our disposition. It cannot well be supposed that man is by nature disposed to be scientific. The scientific fraternity, at any time, are and probably always will be but a small party—a set of freaks, sports from the multitude. They think and talk in a language of their own, as musicians do. The multitude may listen to them at times, with more or less of pleasure, as they do to music; but it is impossible and probably always will be impossible for the many to appreciate the methods and results of the scientific worker. Science, in reality, is a form of art and true artists are never numerous; moreover, it is admitted that they are born—like Topsy, they must grow, for they are not to be made in numbers. Our schools are for the most part in literary hands: and it would almost appear that literary and scientific interests are antagonistic, so unsympathetic has been the reception accorded to Science by the schools.

Parenthetically, let me here deny the accusation not unfrequently made by literary writers that the scientific fraternity are trying to oust literary studies from the schools. Nothing could be further from the truth. We are always craving for better literary training; our complaint is that the methods and subject-matter of literary training are far from being properly developed and, especially, that English is neglected in the schools. Huxley stated the real situation in saying 'Science and literature are not two things but two sides of the same thing.' Our attitude and the difference between the two kinds of training could not be better defined than it is in the following passage from one of his lectures:—

'If I insist unweariedly, nay fanatically, upon the importance of physical science as an educational agent, it is because the study of any branch of Science, if properly conducted, appears to me to fill up a void left by all other means of education. I have the greatest respect and love for literature; nothing would grieve me more than to see literary training other than a very prominent branch of education: indeed, I wish that real literary discipline were far more attended to than it is; but I cannot shut my eyes to the fact that there is a vast difference between men who have had a purely literary and those who have had a sound scientific training.

'Seeking for the cause of this difference, I imagine I can find it in the fact that, in the world of letters, learning and knowledge are one and books are the source of both; whereas in Science, as in life, learning and knowledge are distinct and the study of things and not of books is the source of the latter.

'All that literature has to bestow may be obtained by reading and by practical exercise in writing and speaking; but I do not exaggerate when I say that none of the best gifts of Science are to be won by these means. On the contrary, the great benefit which a scientific education bestows, whether as training or as knowledge, is dependent upon the extent to which the mind of the student is brought into immediate contact with facts—upon the degree to which he learns the habit of appealing directly to Nature and of acquiring through his senses concrete images of those properties of things which are and

always will be but approximately expressed in human language. Our way of looking at Nature and of speaking about her varies from year to year; but a fact once seen, a relation of cause and effect once demonstratively apprehended, are possessions which neither change nor pass away but, on the contrary, form fixed centres about which other truths aggregate by natural affinity.'

The rise of Science is due to the introduction of the experimental method. Mr. Balfour, in arguing, as he has done recently, that Science rests upon many unprovable postulates and therefore does not differ in method from metaphysics, has made assertions which cannot be allowed to pass as correct True Science rests wholly upon fact and upon logic: all else is mere provisional hypothesis—a garment we are prepared to put aside at any moment if cause be shown. We are well aware that human nature is always intervening to spoil our work; it is human to err, and false doctrine may easily occupy the attention for a time, but we are fully conscious of our limitations and prepared to admit them, whilst we feel that we are ever advancing towards security of knowledge.

The method of Science, indeed, is the method of the Chancery Court—it involves the collection of all available evidence and the subjection of all such evidence to the most searching examination and cross-examination. False evidence may be tendered and for the time being accepted; but sooner or later the perjury is discovered. Our method, in fact, goes beyond that of the courts: we are not only always prepared to reconsider our judgments but always searching for fresh evidence; we dare to be positive only when, time after time, the facts appear to warrant a definite conclusion. But there are few instances in which we have travelled so far. The Newtonian theory of gravitation, the Daltonian theory of atoms, are two striking examples of generalisations which fit all the facts, to which exceptions are not known; should any exception be met with we should at once doubt the sufficiency of such theories. In cases such as Mr. Balfour has discussed—the problems of metaphysics and of belief—experiment and observation are impossible: we can only resort to speculative reasoning; our belief, if we have one, is necessarily founded upon intangibilities and desires.

'There was a door to which I found no key:
There was a veil past which I could not see;
Some little talk awhile of Me and Thee
There seemed—and then no more of Thee and Me.'

The awful problem before us at the present time is to decide which direction we will take, to what extent and in what way we have the right to teach things which transcend our knowledge; the way in which truth lies may be clear to some of us but can never be to the majority. Those who wrap up such matters in a tangle of words are not helpful, to say the least. However mellifluous the terms of Bergsonian philosophy may be, they do not bear analysis when the attempt is made to interpret them; their effect is merely sensuous, like that of cathedral music.

But in order that she may lead, Science must herself set an unimpeachable example—far too much that is now taught under the guise of Science is pure dogma; in fact, the philosophy of the schools is mostly dogma. The true legal habit of mind is insufficiently cultivated and but rarely developed even among scientific workers—our logic is too often an imperfect one. In Science, as in ordinary life, party politics run high and scientific workers are usually, for the time being, party politicians. We are too often crass specialists, always very human: indeed, whatever the lines along which Evolution has taken place, they cannot well have been such as to favour in any considerable degree the development of the proclivities which distinguish the scientific inquirer: time after time, doubtless, he has been knocked on the head, and the spread of his kind prevented; now we too often lame him, if we do not kill him, by faulty education.

The difficulties under which Science labours in our schools are partly internal, partly external. Tradition and the type of mind of the average teacher favour set lessons and literary study by blocks of learners; the extra cost of the work is considerable, when the expense of the special requirements is taken into account; more time and more individual effort are demanded both from teacher

and from taught; freedom is hampered by the need of considering the requirements of external examinations; finally, the Universities have done but little to help and though the schools have more or less unwillingly recognised that there is some value in scientific studies, in consequence of the persistent demands men such as Huxley have made, more especially because it is seen that there is money in them, none the less there is still no real demand for them on the part of the public. Of this and, in fact, of nearly all the real problems of education the public are too ignorant to be judges.

Having been more than forty years not only a teacher but also a student of students and of teachers, of educational methods and of the conditions under which teaching is carried on, I have been led to form very definite opinions, the more so as I have been able to regard the problems not only from the pedagogic side but also from that of the chemist and biologist—with some knowledge of the mechanism.

My view—and it is one that I desire to press to a logical conclusion—is that we must recognise that human ability is not merely a limited quantity but that it varies enormously not only in quantity but also in quality: the human orchestra contains a great variety of instruments differing in tone and range, but Nature, like man, makes few instruments of superlative excellence, a vast number of very poor quality and only a moderate proportion of serviceable type. If Science can tell us anything, it is that the democratic and republican ideal of equality is the veriest moonshine—a thing that never has been and never will be. And education can do very little to alter the state of affairs: it cannot change the instrument, at most it can develop its potentialities and it may easily, by careless handling, do damage to the working parts. To take a special case, of interest at the moment, no contention is less to be justified, I believe, than that which has been put forward frequently, of late years, on behalf of women—that their disabilities are in no small measure due to the fact that we have neglected their education: give them time to educate themselves and they will be as men in all things. Years ago, at our Stockport Meeting, I ventured to express the difference by saying that woman is not merely female man but in many respects a different animal: the two sexes have necessarily been evolved to fulfil different purposes. Nothing is more instructive in the history of modern educational progress than the fact that women have asked merely for what men have: at the Universities they have attended the men's courses; not one single course have they demanded on their own account. Higher teaching in relation to Domestic Science so-called has only been thought of very recently and mainly because men have urged its importance. Most serious and, I believe, irreparable injury is being done to women, in London especially, by forcing them to undertake the same studies and to pass the same University examinations as the men: and the damage is done to the race, not merely to individuals, as the effect of education, whether direct or indirect, is clearly to diminish the fertility of the intellectual. Some day, perhaps, when the present wave of selfishness has passed over us, a rational section of women will found a woman's university where women can be taught in ways suitable to themselves without injury to themselves. In saying these things, of course I am laying myself open to the charge of narrowness—in deprecation I can only say, that what we are pleased to call education is, for the most part, so futile in substance and in its results that I shall not mind in the least if I am accused of decrying it: in my opinion, we should all be better without most of it, men and women alike. So far as so-called intellectual education is concerned, learning to read seems to me to be the one thing worth doing: at present it is the thing most neglected in schools.

The commotion raised in pedagogic circles, during the last few months, by Madame Montessori is sufficient proof, if one were wanted, of the hopeless crudity of our educational practices.

To develop a rational system, we need to take into account man's past history and to apply evolutionary and biological conceptions. Education, as we know it and practise it, after all is a modern superstition—something altogether foreign to the nature of the majority of mankind: it is based on the false assumption that we can all be intellectual; whereas most of us can only use

our hands. But the schools neglect hands and attempt the impossible by trying to cultivate non-existent wits. Man is doubtless pretty much what he was and it is useless trying to make of him what he has never been. The harmless vision by which Mr. Wells and other windy idealists are obsessed of a perfect man in a perfect future may safely be left out of account for the present.

We are seeking to educate all. What does this mean? Practically that we are seeking to teach all to read. But when they have learnt, what are the majority to read—what will they care to read? At the schools for young gentlemen, the reading taught hitherto has been mostly the reading of Latin and Greek. We know the result—the number of persons above school age who can and do read either language is negligible. Some of us learn French, scarcely any learn German, Spanish is all but neglected: when, therefore, we visit the Continent of Europe or South America we can only mumble a few words of the language of the country and usually allow the foreigner we visit to speak broken English for us: few of us read his literature.

The vain attempt is made to put us in touch with the past but no real effort is exerted to bring us into contact with the present. We have not yet taught English in our higher schools but are beginning to think of doing so—to this end, we are urging that attention be paid to so-called classical literature, forgetting, of course, that for the most part this was written for grown-ups and not as food for babes of school age.

The difficulty is still greater in the case of those who have only passed through the elementary schools—the literature that will appeal to most of these will be very limited in scope. Our newspapers show pretty clearly what will go down: not much—but it represents what is going on in life. In London, when the theatres are under discussion, it is often said that people want to be amused, not instructed; to cudgel our dull brains is a dull business to most of us. It seems to me that this doctrine should be applied more than it is in the schools. At all events, we shall do well to remember the words of the holy lama in Rudyard Kipling's 'Kim': 'Education is greatest blessing if of best sorts. Otherwise no earthly use.'

To discover the best sort for each sort of student is our difficulty—who will do it? Here comes my point. Not the present race of schoolmaster or of educational authority. By placing classical scholars in charge, we seem unconsciously to have selected men of one particular type of mind for school service—men of the literary type; and this type has been preferred for nearly all school posts, mainly because no other type has been available, this being the chief product of our Universities. Such men, for the most part, have been indifferent to subjects and methods other than literary—I verily believe not because they have been positively antagonistic or lacking in sympathy but rather because of their negative antagonism: of an innate inability to appreciate the aims and methods of any other school of thought than their own, especially on account of their entire ignorance of the experimental method. I believe, moreover, that the difference is fundamental and temperamental, not to be overcome by training. Oxford, owing to the bait of its classical scholarships, seems to have attracted an entirely peculiar type of ability and to stand alone in consequence; at Cambridge, owing to the hold obtained by mathematics, the field has been divided but the mathematician, in his way, is often as unpractical by nature as the classic; fortunately, of late years, owing to the rise of the Medical School and that of Natural Science, other elements have been introduced and the University has a future of infinite promise in consequence, if it will but realise that its primary function is to inculcate wisdom rather than to give purely professional training.

Sympathy is only begotten of understanding: the literary type of mind apparently does not and cannot sympathise with the practical side of modern scientific inquiry, because it has neither knowledge of the methods of experimental science nor the faintest desire for such knowledge.

We need a more practical type of mind for our schools. Pessimist though I may appear to be, having watched with close attention, all my life, the great struggle that has been going on in and between schools—having had the great good fortune also myself to be one of the early workers in the province of

technical education and having been associated with the development of one of the greatest of our boarding schools (Christ's Hospital)—I am, of course, aware that very great progress has been made and am, in every way, hopeful of the future in store for those who are unaffected by present prejudices. In my experience, the men to whom the progress has been due have, in all cases, been trained in a broader school than that of Oxford; the few escapes from Oxford who have been successful reformers have been the exceptions which prove the rule, as they have shown themselves to be gifted with practical instincts: to such men the Oxford literary training has been of extreme value. Oxford will not gain its full value until all types of ability are represented in fair proportion by its students, not one almost exclusively. When this step is taken, the incubus of the Oxford spirit will no longer be upon us: it will then be possible for us to regard education as 'a preparation for life'—a formula often used but usually honoured, hitherto, in the breach, rarely if ever in the observance, in our schools.

You may remember the words addressed to Kim by that wonderful man the Mahbub: 'Son, I am wearied of that *madrissah* (school) where they take the best years of a man to teach him what he can only learn upon the Road.' This is true philosophy—a philosophy that should be noted by the schools, especially those here in Australia.

There must be no misunderstanding. The representatives of literary training rely chiefly on a past into which it is well not to look too closely and must always work with borrowed capital in the days to come: our side has no distant past worth speaking of but is hopeful of a glorious future, in that it will always be adding to its knowledge; we desire to do their party all possible justice and shall ever be in need of their assistance and more than grateful for the service they render us; but it must be war to the knife if they will not recognise that, in a progressive age, they cannot lead any longer, that we shall decline to put up in future with the conceit and narrowness of outlook of the classical scholar.

The argument I have applied to the teacher is equally applicable to the taught—boys and girls, indeed students generally, are of different types: they have different orders of ability and cannot be treated as if all were alike. In the beginning, we may tempt them with all sorts of scholastic diet but only, in the main, in order to discover their aptitudes; when these are found, they should be the main line of attack. In saying this, I am not arguing in favour of extreme specialisation but against time being wasted in attempting the impossible. Some of us can learn one thing, others another; the schools try to force too many into one mould. It is essential that we should try to lay certain foundations but useless to proceed when we find that some of them cannot be laid.

This doctrine is applicable especially to the selection of scholars and to the training of teachers and of evening-class students. We select our scholars almost entirely by literary tests—the result is that we select persons of literary aptitude rather than those gifted with practical ability for every kind of service: like necessarily breeds like. By insisting on 'grouped courses' we too often oblige students to take up subjects which they are incapable of paying attention to with profit: most of us, probably, have found out that there are many subjects which we simply cannot learn, try as we may.

My own experience has been gained in a wide school. My course of action was determined in early days by reading Trench's 'Study of Words,' from which I acquired inklings of the art of inquiry and an interest in tracing things to their origin. At College, at the end of but a single year's didactic study, it was my great good fortune to be honoured with the confidence of my teacher, the discoverer of zinc methyl and the author of the conception of valency, who charged me with the solution of a problem: to work out an absolute method of determining the organic matter in river and well water. Instead of wasting time in merely repeating what others had done, I had to help myself in all sorts of ways: the discipline was invaluable. At the end of a year and a half, on going to Germany to study, I again came under the influence of a man, an individualist of the first water, who encouraged his

students to think for themselves and do things themselves: he was an arch heretic himself and we disputed with him constantly.[1]

When I began to teach, the formal methods in vogue appeared to me unsatisfactory. At first I had to instruct medical students. Then, in 1879, Professor Ayrton and I became associated with the movement to give technical education, in both day and evening classes, started by the City and Guilds Institute. At first we were in temporary quarters; then the Finsbury Technical College was erected—mainly from our designs. Together with Professor Perry, we there developed complete courses of instruction for day engineering students of different types. In 1884 we were transferred to the Central Technical College, South Kensington, where again, in conjunction with our colleagues, Professors Henrici and Unwin, Professor Ayrton and I devised complete courses for engineering students but of a higher grade than at Finsbury.[2] Both colleges were

[1] Those were halcyon times, before the rot had set in which has rendered modern German scientific training a discipline so inferior to that imparted while the high ideals set by Liebig and Bunsen were alone operative: money-making was not yet the object; in fact, the Alizarin patent was only taken out at that time and the Salicylic acid patent a few years afterwards; specialisation was unknown: every student was working at a different problem and everyone knew what everyone else was doing—we constantly discussed our doings together. In later years, each laboratory has had its special subject and the students working with this or that member of the staff, as a rule, have been pledged to secrecy, in case their results might turn out to be of practical value and patentable. The peculiar growth of a new school, that of Physical Chemistry, has also contributed in an unfortunate degree to a change in attitude, the more as it has been pledged to one particular creed.

Mainly through the remarkable influence exercised by Ostwald, an escape from the artistic-literary party, whose voluminous and eloquent writings have had a great vogue, highly speculative doctrine has been put before students not tentatively and argumentatively but as absolute truth: religious doctrine has rarely been professed with greater fervour or with less regard to logic. Workers in this field have not only been neglectful of the organic side of chemistry and altogether lacking in breadth of appreciation but what is even worse—their fingers have not been cultivated.

The two influences combined have deprived the German chemical school of salient features to which formerly it owed its pre-eminence. Fortunately, perhaps, we have not been successful on the commercial side but far too many of us have fallen victims to ionomania and the disease has had dire effects, particularly in biological circles: the text-books are so full of it that the infection will not easily be rooted out.

In recent years several admirable books have been written on the 'pay your money and take your choice' principle, in which the views advocated by A, B, &c., are set down. In discussing these with friends I have been nearly always told: 'Oh, but you must give students some positive belief.' To me it seems that unless the reasons can be stated and their sufficiency considered, we are not teaching anything worthy to be termed Science and in no way promoting the intellectual revolution contemplated by Huxley.

[2] As pieces of original pioneering research work in education, that done at the two colleges has been of great importance; invaluable experience has been gained—yet no one has asked to have the work fully recorded and discussed. As is our English habit, having made an experiment successfully, we put our experience aside and start afresh on a new tack: after being a phenomenal success, at the end of twenty-five years, our system has been abolished at Kensington and a return made to easy conventional ways. New forces are in operation; the last thing we English can contemplate is collective and continuous action.

To pass from small things to great, we once had a Science and Art Department: it was brought into being, with the assistance of Prince Albert, by the late Lord Playfair, who did everything possible, throughout his life, to secure its efficiency; Huxley, Sir John Donnelly and Sir William Abney raised it to a high level; now it is all but abandoned.

Once, in early years, the School Board for London had on its Council a man

distinguished from most others in the country by the completeness of their obligatory courses and by holding an entrance examination, which all students entering upon such courses were required to pass, as well as by the efforts that were made to consider the capabilities of the students and to meet their requirements.

My views were first made public in 1884, when a scheme of instruction was put forward which was eventually developed into that known as the heuristic method. My experience of the method has been gained both in my own school and by watching its application by my pupils and others in a variety of schools—by Messrs. Gordon and Heller in schools under the School Board for London; by Mr. W. M. Heller, of late years, on a very large scale in Irish elementary schools; in a number of girls' schools; in Christ's Hospital school; and during over twenty years in one of the most successful modern secondary schools in the country, where my four sons have been educated, which has grown up at my doors, under a head-master who has been a warm advocate of heuristic teaching.

The subject is discussed so fully in my book on 'The Teaching of Scientific Method' (Macmillan & Co., London, 1903; 2nd ed. 1911) that it is unnecessary to say anything of the method, beyond pointing out that it involves putting the learner in the position of inquirer and insisting that the purpose with which an experiment is made shall be fully appreciated before it is carried out and that the bearing of the result on the question asked at the beginning shall be fully considered—each successive experiment being devised to promote the solution of the problem undertaken and to justify the solution arrived at. One feature of the work is the stress laid on an account being written of the work in proper literary form, stage by stage, as the inquiry is carried on: the art of making experiments is the one before all others to be cultivated by such work; therefore it is essential that a statement of the motive with which an experiment is made shall be written out before proceeding.

The results obtained either by myself or through the agency of those whom I have trained have been most encouraging; but it has only been too obvious that those who attempt to put it in practice, after they have been under the influence of didactic and dogmatic teaching, have the greatest difficulty in acquiring the right habit of mind, so that, probably, not many teachers have really learnt to appreciate the method and its possibilities: it is one that involves too much thinking to please the majority; thinking is always troublesome work. But the movement has had an influence in many quarters and has even affected literary subjects: an ideal has been introduced into teaching the application of which is new, though it is not new in principle. Our conventional method of teaching is not one which favours the development of an inquiring habit—we give demonstrations and we call upon students to verify statements that are made to them; but we are so occupied in stating results, that we do not explain how the results were arrived at and what led up to them. As a rule, only those who have done research work know what constitutes an experiment.

My own experience with students has satisfied me that they not only vary in ability but that the different classes are of very different types of mind: the engineer tends to be constructive but not analytical; the analytical introspective habit of mind is more highly developed in the chemist; the biologist rarely has mathematical proclivities.

It is useless to attempt to teach all in the same way and many can learn only very little.

The explanation of Huxley's failure to forecast the future of Science lies, apparently, in the fact that men generally *are not* attuned to her ways. I am

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of sterling worth, who was a whole-hearted believer in Science—the late Dr. Gladstone: under his influence a most important and successful beginning was made to give very elementary lessons in scientific method in the schools; the experiment came to an end even before his death: the work done by the teacher was so highly appreciated that he was attracted elsewhere and had no proper successor.

We seem, in all things, to depend on some one man: it will rest with Science to remedy this disability from which we suffer so much.

inclined to think that the 'mere man of letters' *will continue* to ignore and despise Science—he will lack the peculiar mental capacity to assimilate scientific teaching. Only the few will rise to a proper understanding of the mysteries and be masters of their subjects, though many may be trained to be skilful mechanics.

The extent to which the multitude can receive instruction is a matter of primary importance. If, as Huxley has said, the greatest intellectual revolution mankind has yet seen is now slowly taking place by the agency of Science—if she be teaching the world that the ultimate court of appeal is observation and experiment, not authority; teaching it the value of evidence: then must we strive to teach all, in some measure, what constitutes evidence, what observation and experiment are.

I believe much can be done in this direction, having made the attempt with hundreds of unwilling students in my time, students of Engineering who had not only made up their minds that they were not going to learn Chemistry as it was not their subject but were incapable of ever entering into the spirit of the work—one of my sons was amongst them. At an early period, having realised that it was useless to waste my time and theirs in the struggle and that it would not help them, in the long run, to give them Chemical tips which they lacked the sense to appreciate and to apply, I made up my mind that it was desirable instead, if possible, to develop any detective or inventive spirit that might be in them, so advised them to read detective stories instead of a text-book and ask themselves what the stories taught them: how the detectives set to work. Their attention was secured by urging them also to think what would be their position, later in life, when they were called upon to act for themselves and to get new knowledge for themselves, if they had not learnt to think for themselves. We have then set them to work to solve a series of problems in the laboratory. The course, in fact, was a combined laboratory-lecture course, the lectures being on and always subsequent to the laboratory work. In not a few cases, in after years, when I have met old students, they have told me spontaneously that, much as they had objected to the pressure put upon them, our insistence on their learning to do something themselves had proved to be of extreme value. Long experience has convinced me that anyone who has once learnt to make simple measurements and observations and to ask and answer a definite question experimentally is on a different mental and moral plane from that occupied by those who have had no such training.

Such teaching is possible even in elementary schools—given competent teachers; but a new race of teachers will be required to carry the work into effect, should it be decided to make the attempt at all generally.

The great mistake that has been made hitherto is that of attempting to teach the elements of this or that special branch of Science: what we should seek to do is to impart the elements of scientific method and inculcate wisdom, so choosing the material studied as to develop an intelligent appreciation of what is going on in the world. It must be made clear, in every possible way, that Science is not a mere body of doctrine but a method: that its one aim is the pursuit of truth.

If we are to progress in these matters, a system must soon be developed which is broader and better than that under which we now muddle along—at present the real problems of education are all but neglected; even if the official mind were capable and desirous of promoting progress, the work of administering rules and regulations—of keeping the machine going—is so great that no time is left for thought.

To accomplish our purpose we need to introduce higher ideals into our University life—the ideals that have long governed the German Universities. In place of the worship of mere knowledge, we must put those of understanding and application and seek to teach all, as far as possible, to appreciate the art of discovery—to value and promote inquiry and discussion: to exercise a reasonable logic, in fact.

We have seen the error of our ways sufficiently to give up payment by results and are all but ashamed that we were ever misled by Robert Lowe to adopt such a soul-killing policy. But none the less our entire educational system is still in

the grips of commercialism and, in this respect, as a nation, we stand alone, I believe. Scholarships, prizes of one kind or another, examinations are the perpetual feast of British education. Examinations, in fact, are a regularised and very lucrative branch of industry—mostly in the hands of certain firms who diplomatically shelter themselves under the ægis of this or that educational body; but the Universities are the greatest sinners. Valuable as examinations may be within certain narrow limits and for certain definite purposes, there is little doubt that our general ignorance is in no small degree determined by our worship of the examination fetish. So long as the system prevails, the education of our youth will not be in accordance either with their capacity or their requirements but on lines corresponding to those by which prize cattle are raised for show—they will be trained to develop some specially catching point.

The examinations are an inheritance from the literary rule. It is possible to test on paper whether a man be 'well read' but faculty as distinct from capacity cannot be so determined. What is worse, by forcing students to commit a large body of doctrine to memory, the attention becomes fixed merely upon what others have done and little time or inclination is left them to acquire a knowledge of method—the faculty of thinking for themselves and applying their knowledge. No class suffer more seriously than medical students under the system—their preliminary training is all but entirely didactic and the time spent upon it all but wasted: we need not wonder that medicine has made so little advance, the practitioners being in no way trained in the use of scientific method.

That we should so long have suffered so futile a system to prevail is incomprehensible. German higher education has achieved marvellous results without any such provision of rewards and prizes as ours and has given breadth to the nation in consequence; in fact, science in Germany is all but a household word, as every family in the educated classes has one or more of its members trained at the University and the primary function of the Universities is to inculcate a knowledge of method: they insist that all who take their degrees shall have inklings of the art of inquiry, not mere knowledge.

To improve our educational system we need to get rid of our blind British belief in 'men of affairs,' especially in the 'man of business,' so-called, really the man of commerce, as persons capable of ordering everybody's affairs and everybody's business. The commercial man, the financier or the lawyer, would never think of calling us in to manage his proper business—why should he be thought competent to manage ours? Results show that he is not, as my argument in this address would lead us to expect would be the case.

No one will seek, for one moment, to minimise the progress made or fail to recognise that infinite credit is due to those who have controlled the work of education thus far; hitherto, however, progress has been made in providing accommodation and getting scholars to school and college: the art of teaching has made no corresponding advance—nor will it, I believe, until the onus is cast more directly upon the teachers and they are forced to exercise greater forethought in the direction of collective action—until they are placed in a position to be sole managers of their own affairs and called upon to row together as entirely self-chosen crews. At home, excepting at our ancient Universities, 'Governing Bodies' are paramount everywhere—not the teachers: and too often the sense of responsibility and power of initiative of the teacher are further diminished by the interposition of a Principal, who may be a man of all affairs except that in hand—the work of teaching. If rumour speak truly, the College President is too often the bar to progress in the United States of America. It is well known that the exercise of responsibility promotes thought and begets the sense and power of accepting responsibility—the opposite is none the less true.

Personally, I have had special experience as to what can be done under a system involving collective action and have had foretastes of what might be done by sympathetic interlocking and correlation of courses: I have no doubt of its superiority: nevertheless, I recognise that such co-operative action may be 'agin Nature.'

In some way, we must learn to debate our doings more freely and not to flinch at fair criticism. Whatever the faults of our English public school

education, one of its many advantages is that boys who go through it are disciplined to stand the kicks of the world without too much complaining: this is one of the marks of the gentleman. Such training is not easily given in the day school and no little difficulty is experienced, I am told, by employers of labour nowadays, on account of the way in which the least criticism, even the suggestion that there may be a better way of doing a thing, is liable to be resented and interpreted as fault-finding by those in their employ.

If the conclusion at which I have arrived be correct—that science is not for the multitude and can never be generally appreciated or even fashionable—in view of the part which it is clearly destined to play in education and in daily life, on account of its infinite and far-reaching influence upon our well-being—the responsibility cast upon the few representatives of science is very great: in support of our civilisation and in order that wisdom may prevail more generally, they must organise its forces effectively.

Whilst individuality is the mainspring of scientific progress, collective action is required to provide full and proper opportunity for the workers and to promote the success of their inquiries. At present, scientific workers are organised merely for the purpose of providing means of publishing the results of their studies, in no way either for defence or offence: our Societies are not effective even for the purposes of debate and criticism. Thus, our chief English scientific Society, consisting of some 500 members representative of all the various branches of physical and biological science, is little more than a rabble—its Fellows are such individualists that scarce half a dozen of us can ever agree to work seriously together for a common purpose, and the irresistible influence we might exercise if we could be unanimous as to our objective is lost to the community. Most unfortunately the Society has no influence whatever either on political or on public opinion: it makes no attempt either to guide the public or to give dignity and importance to the cause of science in the eyes of the community. Its meetings are dull and its belated publications by no means represent the scientific activity of its Fellows. The Presidents of the Society have too often been appointed at an age when the propagandist spirit is no longer paramount, when they have no particular scientific message left in them to deliver. And they occupy the Chair too long: this arises chiefly from the fact that however clear each one of us may be that individually he is fully competent to hold the office, we all agree in finding some objection to every name that is suggested: to overcome this difficulty a short tenure is desirable, so that the compliment can be paid and encouragement given to the various sciences in turn; no one should be appointed to such an office who is more than 60-65 years old, as most of us have used up our ideas and have lost our virility by that age. The other officers also hold their positions too long but members of the Council have far too short a life—consequently all the power is centred in the official body; attempts that have been made to organise the whole Society in sections representative of the various sciences have always been defeated by the official party.

Unless our scientific societies can be made more generally effective, if scientific workers are incapable of learning lessons from administrative life, it stands to reason that the collective interests of Science and of the body scientific must remain unrepresented and unvoiced—to the great detriment of progress and of the public.

Science must be organised, in fact, as other professions are organised, if it is to be an effective agent in our civilisation: the problems pressing upon us are of such magnitude and of such infinite importance that we can no longer afford to be without wisdom.

'That there should one Man die ignorant who had capacity for Knowledge, this I call a Tragedy. . . . The miserable fraction of Science which united mankind, in a wide Universe of Nescience, has acquired, why is not this, with all diligence, imparted to all?' This question, asked long ago by our Chelsea sage, remains shamefully unanswered.

Our present system is cunningly devised to keep expert advice at a distance: unless a row can be made or action taken which will affect votes, little can be done. Persons afflicted with ideas derived from long service and serious study

may obtain a hearing occasionally, at meetings such as this; a leading article or two may be written about their vagaries; but the State has no use for them.

Nevertheless, we must continue to rattle our drums, hoping that the noise will attract in course of time :—

'The future hides in it
Gladness and sorrow;
We press still thorow,
Nothing that abides in it
Daunting us—onward.'

Tarry long we cannot :—

'One moment in Annihilation's Waste,
One moment of the Well of Life to taste—
The Stars are setting and the Caravan
Starts for the Dawn of Nothing—Oh, make haste!'

'God, He knows we need *men* more and more in the game!' said the Mahbub to Kim. The awful war before us must inevitably prove this to be the case, is proving it already; all that I have seen since I came to Australia, to my mind, is proof to the same effect. As Prince von Bülow reminds us, 'the varied life of a nation, ever changing, ever growing more complicated, cannot be stretched or squeezed to fit a programme or a political principle.' The future of this Continent must depend on training being given that will educate and provide real men, not softlings and town-dwellers merely.

The following Papers were then read :—

1. *State Aid for Science: A Retrospect.* *By* C. A. Buckmaster.

An attempt was made to show in what ways and to what extent the State has provided funds for the promotion of Science during the past sixty years, to trace the variations in amount and manner from year to year, and to see what general conclusions, if any, can be drawn from the results.

The sums voted in the Estimates presented to Parliament were taken as a basis, and classified under the two heads of Aid given to Science Instruction and Aid given for the promotion of Scientific Research.

The first of these was again divided into the assistance given to Science teaching in connection with Elementary, Secondary, University, and Technical Education respectively.

The part played by the various Government Departments in this distribution of public funds was indicated, and the effect of this variety on the results of the investigation noted.

Finally the evidence of increase or decrease both in amount and interest was examined and the general results of the inquiry summarised.

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2. *Mathematics and Science as Part of a Liberal Education.* *By* W. D. Eggar.

The methods of teaching the elements of these subjects have been discussed almost *ad nauseam* during the last thirteen years and perhaps longer, the main starting-point being the meeting of the British Association in Glasgow in 1901. It is not the object of the writer of the paper to question the merits of the changes of method either in Mathematics or Science. The immediate cause of the changes has been the change in the character of examinations. Examinations, and, in particular, the school-leaving examination, must always determine the nature and extent of the school teaching. The accepted view is that a boy who has passed this examination has obtained a satisfactory general grounding, and is capable of 'specialising,' as it is called, in Mathematics, Science, Classics, History, Modern Languages, or, at the University, in Law, or Theology, or Metaphysics.

It is maintained by the writer that the Mathematics required by all these

qualifying examinations are either too little or too much. From the purely utilitarian standpoint, the standpoint which is now almost universal, it is only the man in a scientific profession who wants anything more than plain Arithmetic. From the æsthetic standpoint every educated man wants something better than simultaneous quadratics, which mark the superior limit in Algebra. The modern classical Sixth Form boy misses the old logical training of Euclid, which after all did appeal to and influence the clever ones, and has now been replaced by a hotch-potch in which any proof of a theorem is accepted which is good enough for an engineer.

The conditions in science teaching are somewhat similar. Here again everything has been sacrificed to the average stupid boy: the average clever boy is disregarded. The boy without imagination must have everything presented to him with an obvious utilitarian sauce. Hence Science which is not strictly useful but only beautiful is liable to be excluded. You will not find Astronomy and Sound included in many school curricula.

Cannot we arrive at some agreement as to the number and position of the windows of the mind which should be opened by a liberal education? Does the syllabus of any School-leaving or Matriculation or Previous Examination open any? Greek opens a window to the mind which gets as far as being able to read Homer and Plato without a crib and with only occasional use of the dictionary. Physics opens a window when wave-motion in all its forms begins to be realised; the construction of a thermometer or an electroscope leaves the window shut. Mathematics must open many windows for those who go far enough; but the tendency of the average non-mathematical boy is to regard it as a dark and dusty subway with no windows at all. How far must one go to come to a window? The question may be asked in connection with any study; and it might be set as a problem for the Recorder of each Section of this Association to assess the minimum of attainment which will enable the average member to follow with intelligent appreciation the work of that Section.

(A general discussion followed, in which Mr. J. SAXTON, Mr. M. P. HANSON, Mr. G. BLANCH, and Mr. W. JAMIESON took part.)

3. *On some New Motor Tests of Intelligence. By* H. WALKER.

TUESDAY, AUGUST 18.

The following Papers were read:—

1. *The London Trade Schools. By* C. W. KIMMINS, *M.A., D.Sc.*

In order to place the subject of trade schools in its appropriate setting it is necessary to know something of the London County Council's elaborate scholarship scheme, consisting of junior, intermediate, and senior scholarships, which makes ample provision for the very clever child from the elementary school to the secondary school and the University or higher technical school.

After thus making provision for the clever child the problem of problems becomes: How can we prevent the boy and girl of normal intelligence from drifting into the ranks of unskilled labour on leaving the elementary school at the age of fourteen? In order to bridge over the serious gap between the ages of fourteen and seventeen the trade school has come into existence, and is destined in the future to play a very important part in London education. It has been found that for the poor type of child it is, under present conditions, quite impossible to ensure two or three years' continuous instruction after the age of fourteen unless some grant for maintenance is made which will recoup the parents for the loss they sustain by not letting their children enter unskilled employment. The trade school scholarship for boys generally consists of free education and a maintenance grant of 6*l.* for the first year and 15*l.* for the second and third years.

The establishment of the trade school is, moreover, largely due to the changed conditions of modern industry and the total disappearance in some, and the gradual disappearance in others, of the apprenticeship system in many of the London industries. Most of the trade scholarships for boys are awarded in engineering, silversmithing and jewellery, book-production, furniture and cabinet-making, carriage-building, photo-engraving and photo-process work, professional cookery, waiting, and wood-carving, and for the different branches of the building trades. In many other trades, such as tailoring and bakery and confectionery, definite trade instruction is given, but no scholarships are awarded for these subjects. The net cost, apart from loan charges, in a boys' trade school is about 15*l.* to 21*l.* per head.

The scholarships awarded to girls are for trade dress-making, laundry work, upholstery, ladies' tailoring, waistcoat-making, corset-making, millinery, designing and making of wholesale costumes, and photography. As a rule, trade scholarships for girls are for a period of two years, with a maintenance grant of 8*l.* for the first year and 12*l.* for the second year, in addition to free education. The net cost in a trade school for girls is about 15*l.* per girl.

In order to ensure that trade scholarships are given only to children of parents who are unable to maintain their children at school without assistance, no candidate is eligible whose parents or guardians are in receipt of an income which exceeds 160*l.* a year from all sources.

In many ways the trade school has a distinct advantage over the old system of apprenticeship :—

(1) The supervision in a well-equipped trade school is generally of a much more efficient kind than even that of a well-ordered workshop.

(2) Culture subjects are not neglected, and consequently the general education of the boys or girls is continued in a manner suitable to the trade for which they are preparing.

(3) In the apprenticeship system there is a natural tendency for the apprentice to become attached to some special department of the work, to the serious neglect of others.

(4) In following out a definite curriculum under a well-arranged time-table there is very little waste of time and the balance of theoretical and practical work is properly maintained.

(5) The work of a trade school is generally governed by a consultative committee of experts who are to a large extent responsible for the education of the students being carried on under the best trade conditions.

(6) The presence of trade experts with experience of teaching, who are always at hand in the trade school workshop and able to solve any difficulties which may arise, means an enormous saving of time as compared with the case of the apprentice who has to await the convenience of the foreman for the solution of difficulties.

A most important element in the success of the trade schools is the connection of the school with the trade by means of expert consultative committees. The most important of these are the consultative committees in (i) bookbinding, (ii) book-production, (iii) goldsmithing, silversmithing, and jewellery, (iv) tailoring, and (v) furnishing trades. These committees are representative of the Masters' Associations, of the Workmen's Associations, and of the Council. Local consultative committees of experts have also been formed in the case of each trade in each of the girls' schools.

In addition to the full-time trade schools there are many polytechnics and technical schools in London working in conjunction with employers of labour in connection with the technical education of their employés. Moreover, apart from full and part time day work admirable provision is made in all parts of London for evening classes in polytechnics and similar institutions in connection with the various trades. The enthusiasm with which thousands of young artisans, after a long day's work, will attend for theoretical and practical instruction in the scientific principles of their trades under skilled craftsmen is one of the most pleasing features in London education.

2. *Commercial Schools.* By G. T. Moody, *D.Sc.*

3. *The Compulsory Education of Youth.* By Professor J. J. Findlay, *Ph.D., M.A.*

1. Up to the era of the Industrial Revolution all races, savage and civilised, held the youth of both sexes up to eighteen years of age in control and educated them (although only a few were kept at school). The introduction of the factory and of wholesale traffic has created a youthful proletariat, emancipated by earning wages from control either by the family, the Church, or the civic guild.

2. The consequent evil is accentuated (*a*) by the artificial conditions under which the period of childhood is passed in schools: affording few experiences adequate to prepare for precocious emancipation; (*b*) physical conditions of city life; (*c*) opportunities for cheap luxury presenting temptations to idleness and waste—the cinema perhaps the last word in this story; (*d*) the enormously increased demand for monotonous labour which youth can undertake even better than older people.

3. Remedies to be sought by noting how the youth in families of larger means are nowadays educated :—

(*a*) Youth needs social experience; the family and the Secondary Schools together provide opportunities for *corporate life* appropriate to this period of development. The parallel to this among the proletariat is found in Lads' Clubs, the Boy Scout movement, and similar organisations by institutional churches in the slums of large cities; but these cannot claim *control* over the youth. With a selected few they provide outlet for the imagination and foster ideals.

(*b*) Youth needs instruction. The Secondary School for the leisured class, the Trade School for the artizan class, need their counterpart in plans for partial instruction during a few hours in each week compulsorily imposed on all, and taken during the day-time. This is most effective when associated with employment in commerce or manufacture, for youth profits by the discipline of hard work. The Evening Continuation School has failed to reach the great mass of those who need instruction, but has pointed the way to a more comprehensive reform.

(*c*) Youth needs vocational guidance and the personal interest of older folk. The family and the school unite to supply this for the more fortunate classes. Labour Bureaus and the like are beginning to supply it for the proletariat.

4. The organisation needed must make *united* provision for these three needs. It must be set in motion by the State, since the family and the trade have lost the compulsory authority which they formerly exercised; and the State alone can interfere on behalf of the youth with the vested interests of capital and labour. The outcome will be seen in a new type of institution; and a new type of teacher, who will be the guide and friend of youth as well as a 'continuation' instructor. Examples are already to hand in the efforts made by a few large employers of adolescent labour in Europe and America: the State as an employer of such labour has hitherto done little. Reform will only be effective when the social conscience of the community is aroused in large cities so as to support the Legislature in accepting the principle of partial control over wage-earning youth.

4. *Agricultural Education.* By A. D. Hall, *F.R.S.*

(A general discussion relating especially to Victorian experience followed, in which Mr. F. Tate, Mr. Clark, and Mr. Hugh Pye took part.)

5. *Moral Education.* By W. R. Boyce Gibson.

1. Moral instruction has this distinctive characteristic, that it touches the interest on its practical side where the life of ideas is intimately one with the life of sentiment and will. Its appeal is to the personal reason, and the ideas which it stimulates into activity become directive forces of the personal life. Hence moral instruction stands on a different platform from instruction in the

sciences. The ideas we acquire concerning the stars do not modify or otherwise affect their movements. They simply affect our knowledge of their movements. But the ideas we acquire concerning our own behaviour may affect not only our knowledge of that behaviour but the behaviour itself.

2. The ideas awakened through moral instruction will tend to act themselves out, and in thus enacting themselves provide the natural opportunity for moral training. Thus moral instruction and moral training are intimately connected as stages in the completed process of moral education.

3. Since the moral ideas emerge from the depths of the personal life, we shall find it hard on any vital definition of religion to sever moral ideas from their religious setting or moral from religious instruction. In any case it seems inadvisable to sever the two in advance in an artificial way. Teaching that is scrupulously ethical may if it reach deep enough become profoundly religious in its appeal whilst still remaining wholly non-theological and non-sectarian. In our view the exclusion of the child's most natural treasury of morals, the Bible, from courses of moral instruction intended to promote the child's good cannot be logically defended, though it may on lesser grounds be judged expedient.

4. In discussing the conditions of moral instruction it would conduce to clearness if interests were considered in the following order: (1) the child's, (2) the teacher's, (3) the interests of parents and churches. No solution could, of course, be regarded as anything but provisional which did not satisfy all the essential interests involved.

5. Admitting the view of Professor Sadler that 'the question of moral education is the heart of the modern educational problem,' and that 'if this is neglected, education is a peril,' the conclusion of the late International Inquiry dealing with moral instruction and training in schools, that in all public elementary schools at least one lesson a week should be devoted to moral instruction can hardly be considered extravagant.

6. The main part to be played by philosophy in assisting moral education seems to lie (1) in the psychological investigation and analysis of the life and mentality of childhood, (2) in the discussion of the problems and requirements of social ethics, (3) in the organising of a Weltanschauung in the light of which educational ideals in general and those of moral education in particular may be brought into helpful relations to each other and to the rest of life.

(A discussion followed, in which Dr. H. B. Gray and Dr. A. Leeper took part.)

6. *The Teaching of Botany.* *By* Miss L. J. Clarke.

7. *The Teaching of Domestic Subjects in Primary Schools.* *By* Mrs. C. M. Meredith.

The inclusion of any subject in the primary school curriculum needs careful justification because of the limited time available. Each subject must either be useful in the sense that it is to be of service later on, or educational, or both. The domestic subjects are generally regarded as both; but they would probably not be selected on educational grounds alone. Hence it is important to realise exactly what useful result is arrived at and to base the teaching upon this. This aim may be best described as preparation for the more intelligent management of a home, and the teaching should therefore not occupy too much time to the neglect of general education, nor should it be isolated from other subjects which, *e.g.*, provide for amusement and the occupation of leisure. Finally, 'housecraft' should be the subject, to which cooking, sewing, &c., are subordinate.

The main difficulties in teaching housecraft are: (*a*) that the conditions in school are often too unlike those in the girl's future home. Something is now being done to avoid this, but a complete solution is impossible as long as slum conditions still prevail in many working-class homes.

(*b*) That the child has no adequate motive for her work. This is more

important than (*a*), and more difficult to meet, but the following motives can be appealed to :—

(1) The play motive, which is at present only made use of in young children.
(2) The desire to 'help' and to do 'real work.'
(3) The love of simplified or primitive life.

We want to arouse something of the boy scout attitude, which includes a little of all the above motives.

(A discussion followed, in which Mrs. ALLEN and Mrs. MOUNTAIN took part.)

WEDNESDAY, AUGUST 19.

The following Papers were read :—

1. *The Training of the Teacher. By* Dr. JOHN SMYTH.

This paper specially emphasised :—

(1) (*a*) The value of giving young teachers the right ideal; (*b*) The steps in the art of teaching; (*c*) The value of experimental work and especially of experimental schools both in the training of the teacher and in the development of all teachers.

(2) It is well that a student before beginning systematic professional training should :—(*a*) have spent six months or a year in the observation and practice of teaching so as to become acquainted with its problems and difficulties; (*b*) have completed his course of academic training.

(3) It is well for all three classes of student-teachers : Kindergarten, Primary, Secondary, to be trained at the same institution; or, if this be not possible, to learn something of one another's work. A special course of training should be given to intending Rural School teachers.

(4) The training of the teacher naturally divides into three related parts :— The Ideal, Culture and Knowledge, Professional Training. The Ideal may be shortly defined as the spiritual vision of the part to be played by the school in the upbuilding of national life. It is more important than knowledge, and in some ways more important than professional skill. It begets enthusiasm, awakens sympathy with children, and becomes the parent of many virtues. Culture is more valuable than knowledge, as it means at least the kindling of love and appreciation and may mean much more.

(5) The Professional Training of the teacher divides itself into three parts :— (*a*) the lectures on the philosophy, history, administration, principles, and methods of education; (*b*) the observation of and efforts at acquiring skill in teaching; (*c*) the use of experimental work. The first of these may be passed over at present.

(6) With reference to the acquirement of skill the problem for our time is to reduce it by scientific investigation into a series of gradations, and to analyse the whole process into its elements. It will be found that these steps will vary somewhat for each type of student and will be different according as the age is. The elements combining in the perfected result will be the same; and ultimately have all to be mastered, but they may be gained in different ways. Students should be divided into types or classes according to their degree of confidence, their sympathy with children, and their connectedness of thought and speech. Modifications as to the length of time spent on observation and the mode of attack will depend on the grade of teaching for which preparation is being made and on the academic training completed.

(7) The Art of Teaching may be analysed into :—Confidence, planning a lesson, connectedness of thought and speech, sympathy with children, use of illustration, eye and ear power, questioning, disciplinary power. The first three are necessary from the beginning, but each of the others need not be consciously cultivated till the preceding ones have been more or less acquired. The development of power in each should continue to grow consciously step by step

till ultimately all combine in enabling the teacher at every moment to place himself alongside the conscious effort of each individual child and to be fertile in resource to help him.

(8) Experimental work will be the basis and crown of future training. By his laboratory work the student will get a new view of psychology and child-study, and from the experimental schools he will see new vistas of productive effort and inquiry in method, curricula, correlation, &c. It will compel him to be a better teacher, for only the skilful and sympathetic can investigate the recesses of the child mind.

(9) Experimental schools in connection with Teachers' Colleges are as necessary for Education Departments and for all teachers as for the students. They will set new views of the teaching art before teachers and re-awaken zeal and enthusiasm in many. They will be able to demonstrate what correlations can be made, what curricula may be taught, and what methods should be followed. They will substitute scientific certainty for dogmatic opinion or scattered observations, and will give the Teaching Art a new status in the community.

2. *On the General Aims of Training.* *By* Professor J. J. Findlay, *Ph.D.*

3. *On the Possibility of Analysing the Process of Teaching with a View to Simplifying the Approach to the Problem of Training.* *By* Professor J. A. Green, *M.A.*

Sydney.

FRIDAY, AUGUST 21.

After the President had delivered his Address (see p. 592) the following Papers were read :—

1. *Training of Teachers in New South Wales.* *By* Professor A. Mackie, *M.A.*

Prior to 1906 training for teaching was by means of apprenticeship. Boys and girls after the completion of the primary course were apprenticed as pupil-teachers for a period of four years. On the completion of apprenticeship a small number passed into one or other of the two training-colleges. The majority, however, were appointed without further training as assistants in State schools, and thereafter rose to the higher positions partly by length of service, experience, and competency, and partly by sitting for the teachers' examination. In the training-colleges the course was short—after one year of training the students passed out as trained teachers and took their place as assistants.

Growing dissatisfaction with this method of providing a supply of teachers was felt for reasons similar to those operating in England and Scotland about the same time. General dissatisfaction with the school organisations led to a commission being sent to Europe. The report of this commission was the immediate cause of the re-organisation of the educational system which has been proceeding ever since. Further, a syllabus of primary instruction prepared by Mr. Board when he became Under-Secretary in 1905 made it clear that a higher standard of qualification was necessary for teachers.

Guiding principles determining the reshaping of the course of training for teachers were :—

(*a*) The abolition of apprenticeship or the pupil-teacher system.
(*b*) College training for all teachers to be employed in the State service.
(*c*) Longer courses of training than had hitherto been customary.

Since 1906 progress has been steady towards the realisation of these aims: in spite of the very great difficulties in staffing schools in a rapidly developing and widely scattered community there has been no reversion to the policy of employing wholly untrained persons or persons who have picked up their knowledge and skill by means of apprenticeship only.

The Development of Teachers' College.

In 1905 the two colleges were abolished. A single non-residential college for men and women was established in temporary quarters.

Up till 1913 a special entrance examination was held for admission to the college, and since 1910 candidates who had passed the University Matriculation Examination were admitted without further examination.

At first the student body was almost wholly composed of those who had passed through a period of apprenticeship, and, in consequence, courses had to be adopted to suit the needs of ex-pupil-teachers. But gradually the supply of pupil-teachers became exhausted, and their place was taken by probationary students. These were boys and girls passing through a course of secondary training at a High School or District School. During the last two years of this course these probationary students were in receipt of scholarships given to assist them in preparing for the work of teaching. During the last two years of their probationary students' course the pupils received some instruction in teaching and some practice in giving lessons under the direction of the head master and mistress. The Teachers' College also took a part in the supervision of their practice teaching during three months prior to entrance to college.

When the High School courses were reorganised it was decided that the supply of teachers should in future be drawn from those who had completed a four-year course of secondary work. The entrance qualification is now the possession of a Leaving Certificate. In 1914, a transition year, a considerable number were admitted on completion of the first three years of High School work.

The above change precludes the possibility of any preliminary training in teaching before admission. The High School pupil who contemplates teaching as his future occupation is not distracted by having to begin his specific professional training before his secondary course is completed.

The changes outlined above in the character of the student body have been reflected in changes made from time to time in the college course.

The students to whom reference has been made are not sufficient in number to supply the requirements of the teaching service. New South Wales has a scattered population, and this makes necessary a large number of one-teacher schools. Hence the supply of rural teachers is an urgent problem. The reasons which make it impossible to staff such schools with teachers who have had a four-year High School course followed by a college course of at least two years are partly financial, partly due to the character of rural school teaching, and the conditions of life in outlying settlements, and partly the result of the inadequacy of college accommodation at present.

In the past the rural schools were staffed by persons who after a simple examination were placed in larger schools for a period of three months' practice, and thereafter were sent to take sole charge of the small rural school.

This method was abandoned in 1909. In 1910 the college provided a course of training, shorter and simpler than those already in operation, and intended to give a short period of training to the rural school teacher. A short course of six months' training was organised, and has since been continued. Each year about 250 students are trained in this way for rural schools.

The college is organised to provide a variety of courses to meet the varied requirements of the State Department. The courses at present in operation are as follows:—

A short course of six months prepares teachers for the small rural schools.

A one-year course devoted solely to professional work prepares graduates in Arts or Science for Primary or High School teaching. A two-year course prepares either for Infant or Primary teaching. Third and fourth year courses allow of students completing degree courses at the University or taking up some special branch of work.

The division of time between the two parts of the college training—the academic and the professional—varies according to the course. The general tendency is to increase the amount of professional work as the college entrance standard rises. But the shorter courses are more predominantly professional than the longer. Further, the practice is adopted of putting the professional training towards the end of the longer courses.

Teaching Practice for all students in attendance is provided for in the Sydney schools. A large number of schools are made use of in order that only a few may be attached to each school. While engaged in practice-teaching, each group of students is under direction of a member of the college staff who acts as supervisor of practice-teaching.

Some years ago considerable opposition existed to the plan of training teachers without preliminary apprenticeship. Experience does not seem to have justified the fears entertained. No doubt the young teacher, like the young medical man, requires a period of practice to make him a competent practitioner. This is secured partly by requiring a fairly long period of continuous practice immediately antecedent to exit from college, and partly by the probationary period prior to issue of the teacher's certificate of competence. The evidence available goes to show that High School and college training followed by a period of probation produces practitioners of at least good quality as did the apprenticeship system.

The immediate future development will consist in carrying into effect the principles already indicated. The short course of training will be increased from six to twelve months. A larger proportion of the students will enter after completing a sound secondary schooling. The college courses will become still more professional in character.

Under the direction of the college are two Demonstration Schools, the head teachers of which hold the position of lecturers in education on the college staff. A small amount of experimental work is carried out in these schools, some of which has been published.

From time to time the college publishes monographs of educational interest. These are mainly the work of members of the college staff. The stimulus of such work is considerable, and efforts are made to allow those members of the staff who undertake investigations the leisure necessary for carrying them out.

(A discussion followed, in which Professor FINDLAY, Dr. C. W. KIMMINS, and Professor J. A. GREEN took part.)

2. *Problems and Methods in Russian Experimental Pedagogics.* *By* Professor A. NETSCHAJEFF, *Ph.D.*

There is no administrative unity in Russian education. The Ministries of War, Commerce, Public Instruction, Agriculture, and Benevolent Institutions all have educational responsibilities, and the Orthodox Church adds to the complicated list of administrative authorities. This want of unity leads to difficulties in practice, *e.g.*, the transition from primary to secondary school is very difficult. Public opinion moves in the direction of a single type of school of general education for all children.

The autocratic régime of ministers has led to many ups and downs in education, but the fact that repression in one Ministry might be contemporaneous with advance in another has had compensating effects. In recent years the Ministry of Commerce has been particularly active in the encouragement it has offered to private initiative and experiment in education.

Public educational movements began in Russia under Catharine II., due largely to the influence of Comenius and Locke. The first university in Russia (Moscow) was founded in 1755, and at first middle and lower schools were controlled by university professors. This ended with the establishment of a Ministry of Education, and, under a rather barren officialism, the schools became simply imitators of their Western neighbours.

Under Alexander II. new ideals came into being. They were voiced by Ushinsky and Pirogoff, who urged the establishment of Chairs of Pedagogy in

the universities and the scientific study of children. Then followed the period of reaction under Alexander III. The Ministry of Education reduced all its schools to a formal type. Individuality was repressed. The system was vigorously attacked, and finally it was officially admitted that reform was necessary. Active propaganda continues. It has taken many forms, with only one of which it is possible to deal here—experimental pedagogics.

Contrary to Tolstoi and his claim for absolute freedom for the child, the psychological investigator thinks the child needs help in the process of learning to understand himself; and in order to render that help it is the teacher's first duty to learn to understand the child as a phase in the process of the biological development of man.

In 1901 the first laboratory of experimental psychology was opened in Russia at the Pedagogical Museum of the Military Schools. This has become the centre of scientific pedagogy in Russia. Out of this institution have developed the Pedagogical Academy (1907), and a Society of Experimental Pedagogics (1908), which conducts a four-year course of study, and carries on an experimental school. Professor Bechtereff founded in 1908 the Psycho-Neurological Institute in St. Petersburg, and Dr. Rossolimo founded the Institute of Children's Psychology and Neurology in Moscow. Numerous congresses have been held, and 131 schools and societies have purchased a cabinet of simple psychological apparatus for experimental purposes.

The chief problem under investigation during the last fifteen years has been concerned with the changes in the moral life of children as depending upon age, sex, and educational environment. Changes in memory and association have been carefully studied. The general results offer striking evidence in favour of co-education. The study of attention and liability to fatigue confirmed this result. Suggestibility, the relation of amount of sleep to intensity of work and the like, have also been the subject of research.

Further, the specific quality of fatigue induced by special kinds of work have been studied with a view to discovering the best possible balance in the sequence of short exercises. We have also been engaged upon the problem of individual memory types in relation to economy in methods of teaching, and the possibility of improving the naturally weaker sides of individual memory. The 'natural' method of teaching foreign languages has been carefully investigated with a view to determining the respective place to be given (*a*) to the mother tongue and (*b*) to pictures in that work.

Lastly, we have been engaged in comparing the teachers' judgments of children as 'attentive,' 'interested,' 'progressing,' with their performances under stricter laboratory methods and conditions.

The work of Dr. Rossolimo and Professor Lazoursky in characterology should also be mentioned.

These researches have all taken their rise in the laboratory, passed thence to the school, and finally come back to the laboratory again. This triple process seems to us absolutely essential.

(Professor Anderson followed, thanking Professor Netschajeff, on behalf of the University, for presenting the Department of Education with a complete set of his psychological apparatus devised especially for educational investigation.)

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3. *School Training for Public Life.*
By the Rev. H. B. Gray, *D.D.*

Educational methods and practice have been up to the last twenty-five years empirical in England. The science of pedagogy has only recently come on to the horizon and is still in its infancy. Traditional subjects have occupied the attention of schoolmasters even on the highest rungs of the educational ladder, and have been accepted as the groundwork of educational faith, notwithstanding the conclusions of thinkers like Pestalozzi, Rousseau, and Froebel abroad.

Education, which in Germany and the United States has long been welcomed as a great national asset, has in these islands been regarded as little less than a bore. The evolutionary theories of Darwin have, however, gradually penetrated the

domain of pedagogy. It has been discovered among other things that the body and mind are inseparably interconnected, and that the evolution of the child has as its prototype the evolution of the race; secondly, that the higher we go up the scale of creation, the more vast is the difference between the infant and the adult life, and that hence arises not only the capacity but the necessity of education to man as distinguished from the lower animals. This necessity begins from the cradle onwards, and the training of childhood in the informal education of the home becomes infinitely important. These theories, however, can only be touched upon in passing, as the special subject of the Paper is the school or formal training for public life.

Success and value in public life presuppose a well-balanced and ordered education. Such an education can only be gained by a due balance between the study of the works of Nature and the works of man, between linguistic and literary subjects on the one hand, and mathematical and natural-scientific subjects on the other. The adolescent who has been trained in the one to the exclusion of the other emerges as a narrow man. This pedagogic principle has been but slowly recognised in our ancient universities and historic public schools, which have derived their curricula by long tradition from the ecclesiastical seminaries of four centuries ago, although the Humanists were regarded originally as the foes of the Church. The persistence of class interests and class prejudices in England has kept this tradition alive, long after a philosophic pedagogy recognised its inherent unwisdom.

A long race of schoolmasters also, trained on the narrow ancient methods, has perpetuated the superstition, and has not yet by any means shaken off the trammels. Their want of intellectual equipment in other subjects has been a collateral drawback—and this notwithstanding calls, more or less intelligent, from the industrial classes, and from the more progressive ideals of other nations.

The devotion to literary and linguistic to the exclusion and disparagement of scientific studies in the curricula of our universities and schools carries with it, to a certain extent, a justification, inasmuch as it is undoubtedly true that concentration on the struggles and achievements of men in the past confers on the aspirant to public life a greater power of expressing himself more clearly and forcibly, of impressing his views and convictions on other men. On the other hand, his ignorance of the laws of Nature, and want of practice in tracing from the laws and phenomena of the known to the laws and phenomena of the unknown, have a tendency to give him a narrow outlook on the social and political problems with which he has to deal in governing and regulating the lives and ameliorating the condition of his fellow-men.

This becomes more painfully apparent when he is brought into contact with the phenomena of a vast and complicated Empire, and not merely of an insular people. It is not surprising, therefore, that the policy of our statesmen and public men generally has been lacking in (what may be called) imperial instinct, and this lack of a wide horizon may constitute a real danger to the future integrity and consolidation of the Empire.

To descend, then, from the general to the particular, the youthful aspirant to public life ought to spend far less time in the study of the two ancient languages which (until the past twenty-five years) occupied more than three-quarters of the educational periods of the young among the governing classes. He ought to devote not more than one-quarter or one-sixth of his student-life to such subjects. Political and commercial geography, a thorough knowledge of one modern language, of English literature and European and English history, ought to be part of his intellectual equipment. Civics and political economy ought to be carefully studied; while on the scientific side he should be taught at least the elements of physics and chemistry, and electricity, with a certain amount of general applied mathematics. The connection between mind and hand in manual training should also be a part of each student's equipment.

With regard to the social side of school-life, the great weakness, both in our schools and universities, has been a want of large outlook. Both types of institutions are excellent training-grounds for character: in both the adolescent learns effectively the knowledge how to command and how to obey. But the sympathy and camaraderie engendered have been confined to those of the boy's own rank and position in life. The republic in which he

is trained instils strong local patriotism, which, however, is intensive rather than extensive. His angularities are rubbed off, and his power of command is well trained. Hence he becomes, as a public man, if he attains to responsible positions in his island home, a sensible and just ruler within certain limits, but he perpetuates the prejudices of the class system. For the same reason, when his functions call him to the outlying parts of the Empire, he becomes an excellent governor over uncivilised races and over subject-peoples which, while not inferior to himself in civilisation, have been accustomed to domination through the centuries. But in countries like Australia, New Zealand, and Canada he is often, at first at least, a comparative failure, through the causes already enumerated, *i.e.*, class-prejudice, want of wide sympathy, an insular distaste for customs and habits with which he is not familiar, and a lack of manual training in early life. In fact, the majority of English boys have, except in the narrow area of school-sports, very little knowledge of the scientific connection between mind and hand. Some improvement, however, in all these respects has been observable during the last ten years, but much more wide-spread educational reform is required to make our statesmen less insular and fit them for the government of their imperial estate. It is indeed these deficiencies that our brethren Overseas, and those of us who have divided our lives between our Island Home and our wide-flung Dominions, consider should be taken in hand and remedied in our schools and colleges if our vast and complex Empire is to survive as an organic whole.

(A discussion followed, in which Professor FINDLAY, Professor H. E. ARMSTRONG, and Professor J. A. GREEN took part.)

TUESDAY, AUGUST 25.

The following Papers were read :—

1. *The University and the State.* *By* Sir H. R. REICHEL.

2. Mr. P. BOARD dealt with the same problem from the point of view of the State.

3. *The School and the University.* *By* Professor J. A. GREEN.

(Dr. H. B. GRAY and Professor A. MACKIE followed.)

The following Paper was taken as read :—

4. *Educational Pioneering (Queensland.)* *By* J. D. STORY.

1. The difficulties which have to be overcome by the Queensland Education Department, in its efforts to give to each child the rudiments at least of a primary education, will be understood when it is realised that the State contains 670,500 square miles; a total population of 656,224; a primary school population between the ages of five and fifteen of 138,551; individual holdings of 2,900 square miles each; and some places a journey of at least two weeks from the Departmental base. The success of the Department in its efforts may be gauged from the fact that, according to the latest statistical returns of the Commonwealth, the percentage of Queensland children between the ages of five and fourteen who can read and write is no less than 92·69, while the percentage of children of the same age who cannot read is as low as 6·82. These figures it may be remarked are the best for any of the Australian States.

2. As auxiliaries to the ordinary full-time schools, there is a system of travelling teachers, Saturday schools, week-end schools, part-time schools, house-to-house schools, and railway-construction camp schools. The last-named are particularly necessary because of the rapid extension of railway facilities. The

State has already constructed 4,730 miles of railway at a total cost (including rolling-stock) of slightly over 34,000,000*l*., which for the last financial year returned 3*l*. 8*s*. 8*d*. per cent. interest; Parliament has approved of an additional 1,406 miles on which work has not yet been begun; and there are 301 miles in course of construction at present. Many of the men employed in the construction have their families with them; and provision is made for the education of their children by means of tent schools, which can be readily transported from one camp to the next as the work progresses.

3. The travelling-teacher system is designed to meet the educational needs of districts so sparsely populated, and with families so isolated, that at no one centre can a sufficient number of children be collected to warrant the establishment of a school. The system, which has proved a great success, was initiated in 1901, when one travelling teacher was appointed; there are at present 17, and from the beginning of 1915 the number will be increased to 20. This teacher must be a man of special qualifications, a knowledge of 'bushcraft' being indispensable; but the Department supplies him with a buggy, horses, and camp equipment, as well as allowing him the services of a lad to tend the horses and otherwise assist. It is the duty of the travelling teacher to ascertain what scattered families with children requiring education are resident in the district assigned to him, and to visit every such family at least four times a year. He stays as long as possible at each visit, teaches the children, revises the work set at the preceding visit, prescribes the new work to be attempted, and advises and helps the member of the family—usually an elder sister—on whom devolves the duty of instructing the children during his absence. A much-appreciated feature in connection with the travelling teacher is that he carries with him a stock of school library books for lending to children and parents, and of Departmental School Papers for distribution among his pupils, thus providing a supply of cheap and wholesome literature in the out-of-the-way places to which his duties take him. In the discharge of their duties during 1913 the 17 travelling teachers covered a total distance of 60,438 miles, visited 900 families, and instructed 1,884 children.

4. Secondary education in Queensland has always been well provided for, and secondary education is free to all who pass the qualifying examination; there is also a liberal system of sustenance allowances for the children of parents of modest means. Scholarships to the University are also granted, and in addition to free tuition these scholarships carry sustenance allowances.

5. Compulsory attendance carries with it the obligation to safeguard the health of the children who attend; and, accordingly, a scheme of medical and dental inspection—aiming at the practically useful rather than the scientifically exhaustive—has been evolved. The Department has two full-time and four part-time medical officers, one full-time ophthalmic inspector, and three full-time dental inspectors. In addition, the State at large liberally endows its hospitals, contributing two pounds for each pound locally subscribed, with the result that there are 90 well-equipped public hospitals; and at 28 of these the Department has arranged that, in return for a small annual payment, the hospital doctor shall attend to the children in his centre.

6. Queensland upholds the Commonwealth scheme of defence and is giving the movement warm support; male teachers are being trained as cadet instructors, and female teachers in charge of small schools are being given an appropriate course of instruction, so that they may train their elder male pupils and generally improve the physique of the children in their charge, irrespective of sex.

7. Queensland has many empty spaces to be filled by a yeoman population; the Education Department recognises that parents will not go to places where their children cannot be educated, and that the Department must do its part in encouraging settlement by making education available in every possible way, so that the vision may be realised of a Queensland fully occupied by a contented and happy people, a Queensland forming a strong outpost of the Empire, contributing to her prosperity in times of prosperity and ready to answer her call in the hour of her need.

Section M.—AGRICULTURE.

President of the Section.—A. D. Hall, M.A., F.R.S.

The President delivered the following Address at Adelaide on Wednesday, August 12 :—

The President of a Section of the British Association has two very distinct precedents before him for his Address; he can either set about a general review of the whole subject to which his Section is devoted or he can give an account of one of his own investigations which he judges to be of wider interest and application than usual. The special circumstances of this meeting in Australia have suggested to me another course. I have tried to find a topic which under one or other of its aspects may be equally interesting both to my colleagues from England and to my audience who are farming here in this great Continent. My subject will be the winning of new land for agriculture, the bringing into cultivation of land that has hitherto been left to run to waste because it was regarded as unprofitable to farm. To some extent, of course, this may be regarded as the normal process by which new countries are settled; the Bush is cleared and the plough follows, or under other conditions the rough native herbage gives way to pasture under the organised grazing of sheep or cattle. I wish, however, to deal exclusively with what are commonly termed the bad lands, inasmuch as in many parts of the world, though recently settled, agriculture is being forced to attack these bad lands because the supply of natural farming land is running short. In a new country farming begins on the naturally fertile soils that only require a minimum of cultivation to yield profitable crops, and the new-comers wander further afield in order to find land which will in the light of their former experience be good. Before long the supply is exhausted, the second-class land is then taken up until the stage is reached of experimentation upon soils that require some special treatment or novel form of agriculture before they can be utilised at all. Perhaps North America affords the clearest illustration : its great agricultural development came with the opening up of the prairies of the Middle West, where the soil rich in the accumulated fertility of past cycles of vegetation was both easy to work and grateful for exploitation. But with the growth of population and the continued demand for land no soils of that class have been available for the last generation or so, and latterly we find the problem has been how to make use of the arid lands, either by irrigation or by dry-farming where the rainfall can still be made adequate for partial cropping, or, further, how to convert the soils that are absolutely poisoned by alkali salts into something capable of growing a crop. You yourselves will supply better than I can the Australian parallels, at any rate we in England read that the wheat-belt is now being extended into districts where the low rainfall had hitherto been thought to preclude any systematic cropping.

Now, the fact that the supply of naturally fertile land is not unlimited reacts in its turn upon the old countries. During the 'eighties and 'nineties of the last century the opening up of such vast wheat areas in America, Argentina, Australia, and the development of the overseas trade reduced prices in Europe to such an extent that in Great Britain, where the full extent of the competition was experienced, the extension of agriculture came to

an end despite the continued increase of population. The area of land under cultivation has declined but little despite the growth of the towns, but the process of taking in the waste lands stopped and much of the land already farmed fell back from arable to cheaper pasture. But as soon as production in the newer countries failed to keep pace with the growth of population prices began to rise again, and we are now in the old world endeavouring to make productive the land that has hitherto been of little service except for sport and the roughest of grazing. Even the most densely populated European countries contain great areas of uncultivated land; within fifty miles of London blocks of a thousand acres of waste may be found, and Holland and Belgium, perhaps the most intensively cultivated of all Western countries, possess immense districts that are little more than desert. Of the European countries, Germany has taken the lead in endeavouring to bring into use this undeveloped capital; her population is rising rapidly and her fiscal policy has caused her to feel severely the recent increase in the prices of foodstuffs, which she has determined to relieve as far as possible by extending the productivity of her own land. It has been estimated that Germany possesses something approaching to ten million acres of uncultivated land and a Government department has been created to reclaim and colonise this area.

Before dealing with the processes by which the rough places of the earth are to be made straight there is one general question that deserves consideration—Is it more feasible to increase the production of a given country by enlarging the area under cultivation or by improving the methods of the existing cultivators? There is without doubt plenty of room for the latter process even in the most highly farmed countries: in England the average yield of wheat is about 32 bushels per acre—a good farmer expects 40; the average yield of mangolds, a crop more dependent upon cultivation, is as low as 20 tons per acre when twice as much will not be out of the way with good farming. A large proportion of the moderate land in England is kept in the state of poor grass—even as grass its production might be doubled by suitable manuring and careful management, while under the plough its production of cattle-food might easily be trebled or quadrupled. Why, then, trouble about adding to the area of indifferent land when so much of what has already been reclaimed, upon which the first capital outlay of clearing, fencing, roadmaking, &c., has been accomplished, is not doing its duty? We are at once confronted by the human factor in the problem. The existing educational agencies which will have to bring about better farming will only slowly become effective, and however imperfect they still may be in England, they are mainly so because of the lack of response upon the part of the farmers. The present occupiers of the land do obtain in many cases a very inadequate return from it, but they make some sort of a living and they hold it up against others who, though they want land, cannot be guaranteed to use it any better. Improved farming means more enterprise, more knowledge, often more capital, and the man who can bring these to the business is far rarer than the man who, given a piece of land even of the poorest quality, will knock a living out of it by sheer hard work and doggedness. While, then, there should be no slackening in our efforts to improve the quality of the management of existing land, there is a case for also using every effort to increase the cultivable area; indeed, it is probable that for some time to come the second process will add most to both the agricultural production and the agricultural population.

Let us now consider what are the factors which determine the fertility of the land that is first brought into cultivation and remains the backbone of farming in the old settled countries. Foremost comes rainfall, and the distribution is almost as important as the amount. Winter rain is more valuable than summer, and though cereal-growing is none the worse and may even obtain better results with a rainless summer, stock-raising and the production of fodder crops are the better for a rainfall that is distributed fairly evenly throughout the year. Rainfall, again, must bear some relation to temperature; some of the best farming in the Eastern Counties of England is done on an average rainfall of 20 inches; there are great areas in South Africa with the same average rainfall that are little better than desert. In temperate regions we may say that the naturally fertile land requires a rainfall of from 20 to

50 inches per annum, not too much segregated into seasons and some at least falling in the winter.

If the rainfall is excessive or the drainage inadequate to carry it off, the formation of peat is induced, resulting in such uncultivated areas as the bogs of Ireland and the moors of Eastern England, Holland, and Germany.

Given suitable rainfall and temperature the texture of the soil becomes a factor of importance; if too coarse and sandy, so little of the rainfall is retained that we get all the effects of drought secondarily produced. In itself the open texture of a coarse sandy soil is favourable to plant development; under irrigation, or where the situation is such as to result in permanent water a short distance below the surface, fine crops will be produced on sandy soils that would remain almost barren if they only depended upon the rainfall for their water. In Western Europe large areas of heaths and waste land owe their character to the coarse and open texture of the soil. At the opposite extreme we find clays so heavy that their cultivation is unprofitable; such soils, however, will carry grass and are rarely left unoccupied. For example, in the South-East of England there are a few commons, *i.e.*, land which has never been regarded as worth enclosing and bringing into particular ownership, situated on heavy clay land; most of such land is pasture, often of the poorest, or, if at any elevation, has been covered with forest from time immemorial.

One last factor in the soil is of the utmost importance to fertility and that is the presence of lime—of calcium carbonate, to be more accurate—in quantities sufficient to maintain the soil in a neutral condition. Old as is the knowledge that lime is of value to the soil, we are only now beginning to realise, as investigation into the minute organisms of the soil proceeds, how fundamental is the presence of lime to fertility. A survey of the farming of England or Western Europe will show that all the naturally rich soils are either definitely calcareous or contain sufficient calcium carbonate to maintain them in a neutral condition even after many centuries of cultivation. Examples are not lacking where the supply of calcium carbonate by human agency has been the factor in bringing and keeping land in cultivation. I have discussed one such case on the Rothamsted estate and several others have come under my notice. The amelioration of non-calcareous soils by treatment with chalk or marl from some adjacent source has been a traditional usage in England and the North of France: Pliny reports it as prevailing in Gaul and Britain in his day, and the farmer of to-day often owes the value of his land to his unknown predecessors who continuously chalked or marled the land. Upon the presence of carbonate of lime depends the type of biological reaction that will go on in the soil, the beneficial bacterial processes that prepare the food for plants only take place in a medium with a neutral reaction. The Rothamsted soils have provided two leading cases. I have shown that the accumulation of fertility in grass-land left to itself and neither grazed nor mown, so that virgin conditions were being re-established, was due to the action of the organism called Azotobacter, which fixes free nitrogen from the atmosphere, and was indirectly determined by the presence of calcium carbonate in the soil, without which the Azotobacter cannot function. Examination of typical examples of black soils from all parts of the world, the prairies of North America, the steppes of Russia and the Argentine, New Zealand and Indian soils, showed in all of them the Azotobacter organism and a working proportion of carbonate of lime. Now, as we know, all virgin soils are not rich, and only in a few parts of the world are to be found those wonderful black soils that are often several feet in depth and contain 10 to 20 per cent. of organic matter and 3 to 5 parts per thousand of nitrogen. These soils are all calcareous, they occur in regions of a moderate rainfall inducing grass-steppe or bush conditions, and the annual fall of vegetation provides the organic matter which the Azotobacter requires as a source of energy in order to fix nitrogen. Non-calcareous soils under similar climatic conditions do not accumulate nitrogen and become rich; in the absence of carbonate of lime the nitrogen-fixing organisms are not active, and the soil only receives from the annual fall of vegetation the nitrogen that was originally taken from it. There is but a cyclic movement of nitrogen from the soil to the plant and back again, whereas in the calcareous soils there is also continuous addition of fresh

nitrogen derived from the atmosphere, in which process the carbonaceous part of the annual crop supplies the motive power.

The other leading case to be found at Rothamsted is that of certain grass-plots which have artificially been brought into an acid condition by the continued application of sulphate of ammonia. In these soils nitrification is suspended, the nitrification organisms have even disappeared, though the herbage still obtains nitrogen because most plants are able to utilise ammoniacal nitrogen as well as nitrates. The interesting feature, however, is that the decaying grass on these acid soils passes into the form of peat, a layer of which is forming upon the surface of the soil, though nothing of the kind is found on adjacent plots where the use of lime or of alkaline manures has prevented the development of acidity. From this we may learn that the development of a surface layer of peat, independent of waterlogging (when another kind of peat forms even under alkaline conditions), is determined by the acidity of the soil, when certain of the bacterial processes of decay are replaced by changes due to micro-fungi which do not carry the breaking-down of organic matter to the destructive stage. This affords us a clue to the origin of many areas of upland peat in the British Isles, where the remains of ancient forest roots and stumps of trees are found on the true soil surface below the layer of peat, but where there is no water-logging to bring about the death of the trees and the formation of peat. We may suppose that when the land-surface became fit for vegetation at the close of the glacial epoch it covered itself with a normal vegetation, chiefly dwarf forest, because of the rainfall and temperature. The soil, however, being without carbonate of lime, would in time become acid with the products of decay of the vegetable matter falling to the ground, and as soon as this acid condition was set up peat would begin to form from the grassy surface vegetation. The process would continue until the acid conditions and the depth of the accumulating layer of peat would kill the trees, the stumps of which would remain sealed up below the peat. I am far from thinking that this explanation is complete, but at least we have facts in sight which could lead one to suppose that a non-calcareous soil originally neutral and carrying a normal vegetation can naturally become acid, alter the character of its vegetation and clothe itself with a layer of peat. The point of economic importance is that these peaty acid soils are of very little value as long as they are acid, though they take on a quite different aspect if they are limed and made neutral.

Of all the soil factors making for fertility I should put lime the first; upon its presence depend both the processes which produce available plant food in quantities adequate for crop-production at a high level and those which naturally regenerate and maintain the resources of the soil; it is, moreover, the factor which is most easily under the control of the agriculturist.

I need say little about those cases in which infertility is due to the presence in the soil of some substance which is actually injurious to plant-growth, because such substances are nearly always due to the physical environment of the soil, to too much or too little water. In waterlogged situations we may find in the soil peaty acids, iron salts, sulphides, &c., inhibiting the growth of plants; in arid regions the soil may still be charged with an excess of soluble compounds of the alkalis and alkaline earths, resulting from the decomposition of the rocks that have been broken down to form the soil, but which through the inadequate rainfall have never been washed out. The establishment of normal conditions of growth, irrigation in the one case, drainage in the other, will speedily result in the removal of the deleterious substances. Practically, only bodies that are soluble can get into a plant to injure it, hence such bodies can be removed from the soil by water, provided that the water can find its way through the soil and escape.

Let us now consider the various methods by which land suffering from one or other of the disabilities we have just discussed is nowadays being brought into cultivation. The most important, if we consider the area affected, is the extension of cropping into regions of deficient rainfall by means of what has been termed dry-farming. As far as its immediate methods go, dry-farming consists in nothing more than the application of the principles of husbandry

worked out by English farmers in the East and South-East of England, principles first expounded by Jethro Tull, though a complete explanation was not then possible, even if it is now. In the first place, the tilth must be made both deep and fine, thus whatever rain falls will be absorbed and the conditions favouring a deep and full root range will have been established. Next, the soil below the surface, though finely worked, must be compact, because only thus can the water present travel to the roots of the plant. Lastly, a loose layer must be maintained on the surface, which, though dry itself, acts as a screen and a barrier to prevent loss of water from the effective soil below by any other channel than that of the plant. Granted these methods of cultivation, the new feature about 'dry-farming,' which has been introduced by settlers in the arid districts of Australia and North America, is the use of a year of bare fallow in which to accumulate a supply of water for the next year's or two years' crop. This raises the fundamental question of how much water is necessary for the growth of an ordinary crop. The first investigation that Lawes and Gilbert carried out at Rothamsted dealt with this very point; they grew the usual field crops in pots, protected the surface of the soil from evaporation so that all the loss of water proceeded through the plant, weighed the water that was supplied from time to time, and finally weighed the produce, expressing their results as a ratio between the dry matter produced and the water transpired by the plant. These experiments have been repeated under different climatic conditions by Hellriegel in Heidelberg, by Wollny in Vienna, by King and others in America. Now the two processes in the plant, carbon assimilation and transpiration, are not causally connected, though as both are carried out in the leaf and have some factors in common they are found to show some constancy in their relative magnitudes. Lawes and Gilbert obtained a ratio of about 300 lbs. of water transpired for each pound of dry matter harvested, but the other investigators under more arid conditions found much higher figures, up to 500 and even 700 to 1. Now, a crop yielding 20 bushels of wheat per acre will contain about a ton of dry matter per acre, so that, taking the high ratio of 500 to 1, no more than 500 tons of water per acre or 5 inches of rain will have been consumed in the production of this crop. It is, of course, impossible to ensure that all the rain falling within a year shall be saved for the crop; much must evaporate before it reaches the subsoil where it can be stored, and only when the crop is in full possession of the land can we expect that all the water leaving the soil shall go through the crop. What proportion the waste bears to that which is utilised will depend not only on the degree of cultivation but upon the season at which the fall occurs; summer showers, for example, that do not penetrate more than a few inches below the surface will be dissipated without any useful effect. When the climatic conditions result in precipitation during the winter, the water will be in the main available for crop-production; and it has been found by experience that cereals can be profitably grown with as small a rainfall as 12 inches. The necessary cultural operations consist in producing such a rough surface as will ensure the water getting into the subsoil, hence autumn ploughing is desirable. Where the precipitation is largely in the form of snow, a broken surface also helps both to absorb the thawing snow and to prevent it being swept into the gullies and hollow places by the wind. On some of the Russian steppes it has become customary to leave a long stubble in order to entangle as much snow as possible, but probably a rough ploughing before the snowfall would be even more effective. When the rainfall drops to the region of 12 to 16 inches and occurs during the summer months, then dry-farming methods and the summer fallow become of the first importance. The deep cultivation ensures that the water gets quickly down to the subsoil away from danger of evaporation, and the immediate renewal of a loose surface tilth is essential in order to conserve what has thus been gained.

In connection with this dry-farming there are several matters that still require investigation before we can decide what is the minimum rainfall on which cultivation can be profitable. In the first place, we are only imperfectly informed as to the relation between rainfall and evaporation. At Rothamsted there are three drain-gauges side by sidé, the soil layers being 20, 40, and 60 inches deep respectively. The surface is kept rough and free

from growth, though hardly in the condition of looseness that could be described as a soil mulch. Yet the evaporation, even under a moist English atmosphere, amounts to one-half of the annual rainfall, and the significant thing is that the evaporation is approximately the same from all of the gauges and is independent of the depth of subsoil within which water is stored. Evaporation, then, would seem to be determined by surface alone, but we are without systematic experiments to show how variations in the surface induced by cultivation will alter the rate of evaporation. A knowledge of the evaporation factor would then inform us of what proportion of the rainfall reaches the subsoil; we then want to know to what extent it can be recovered and how far it may sink beyond the reach of the crop. It is commonly supposed that the subsoil below the actual range of the roots of the crop may still return water by capillarity to the higher levels that are being depleted, the deeper subsoil thus acting as a kind of regulating reservoir absorbing rain in times of excess and returning it when the need arises. But some work of Leather's in India and Alway's on the great plains of North America throw doubt on this view, and would suggest that only the layer traversed by roots, say, down to a depth of 6 feet, can supply water to the crop; the water movements from the deeper layers due to capillarity being too slow to be of much effect in the maintenance of the plant. The evidence on either side is far from being conclusive and more experiment is very desirable.

It would also be valuable to know how far evaporation from the bare soil can be checked by suitable screens or hedges that will break the sweep of the wind across the land. In England hedges have always been looked at from the point of view of shelter for stock; we find them most developed in the grazing districts of the west, while bare open fields prevail in the east and south. Yet the enormous value of a wind-screen to vegetation can be readily observed, and the market-gardeners both in England and the still dryer districts of the south of France make great use of them. Lastly, we must have more knowledge about the relation between transpiration-water and growth : we do not know if the high ratios we have spoken of hold for all plants. Xerophytic plants are supposed to be possessed of protective devices to reduce loss of water. Are they merely effective in preserving the plant from destruction during the fierce insolation and drying it receives? and do they enable a plant to make more growth on a given amount of water? Wheat, for example, puts on its glaucous waxy bloom under dry conditions. Is this really accompanied by a lower rate of transpiration per unit surface of leaf? and is it more than defensive, connoting a better utilisation of the water the plant evaporates?

The cultivation of these soils with a minimum rainfall necessitates varieties of plants making a large ratio of dry matter to water transpired and also with a high ratio between the useful and non-useful parts of the plant. Mr. Beaven has shown that the difference in the yields of various barleys under similar conditions in England are due to differences in their migration factors : the same amount of dry matter is produced by all, but some will convert 50 per cent. and others only 45 per cent. into grain. This migration ratio, as may be seen by the relation between corn and straw on the plots at Rothamsted, is greatly affected by season; nevertheless Mr. Beaven's work indicates that under parallel conditions it is a congenital characteristic of the variety and therefore one that can be raised by the efforts of the plant-breeder. The needs of dry-land-farming call for special attention on the part of the breeder to these two ratios of transpiration and migration.

Closely linked up with the problems of dry-land-farming are those which arise in arid climates from the use of irrigation-water on land which is either impregnated with alkaline salts to begin with or develops such a condition after irrigation has been practised for some time. The history of irrigation-farming is full of disappointments due to the rise of salts from the subsoil and the subsequent sterility of the land, but the conditions are fully understood and there is no longer any excuse for the disasters which have overtaken the pioneers of irrigation in almost every country. Sterility may arise from two causes—overmuch water which brings the water-table so close to the surface that the plants' roots may be asphyxiated, or the accumulation

by evaporation of the soluble salts in the surface layer until plants refuse to grow. The annual cutting off of the cotton crop in Egypt as the water-table rises with the advance of the Nile flood affords a good example of asphyxiation, but in the neighbourhood of irrigation canals we also find many examples of sterility due both to the high water-table and an accompanying rise of salts. The governing principle is that drainage must accompany irrigation. Even if free from salts at the outset the land must accumulate them by the mere evaporation of natural waters, and they will rise to the surface where they exert their worst effect upon vegetation, unless from time to time there is actual washing through the soil and removal of the water charged with salt. Without drainage the greater the quantity of water used the greater the eventual damage to the soil, for thereby the subsoil water-table carrying the salts is lifted nearer to the surface. With a properly designed irrigation system the danger of salting ought not to occur; there are, however, many tracts of land where the supply of water is too limited to justify an expensive scheme of irrigation channels with corresponding drainage ditches at a lower level. Take the case of a single farmer with some water from an artesian well at his disposal, with perhaps little rainfall, with land subject to alkali, and no considerable natural fall for drainage. If he merely grades the land and waters it, sterility rapidly sets in; the only possibility appears to be to take a comparatively limited area and to cut out drainage ditches or tile drains 4 or 5 feet below the surface, even if they have to be led into a merely local hollow that can be abandoned to salt. The bed thus established must then be watered at any cost until there is a flow in the drains, after which the surface is immediately cultivated and the crop sown. There should be no further application of water until the crop covers the land, the use of water must be kept to a minimum, and by the ordinary methods of dry cultivation evaporation must be allowed only through the crop, not merely to save water but to prevent any rise of salt. With a loose surface and wind-breaks to minimise evaporation it has thus proved possible to grow valuable crops even on dangerously alkaline land. Superphosphate and sulphate of ammonia have proved to be useful fertilisers under these conditions; both tend to prevent the reaction of the soil becoming alkaline, and the calcium salts of the superphosphate minimise the injurious effects of the sodium salts that naturally accumulate in the land. On the other hand, nitrate of soda is a dangerous fertiliser. Attempts have been made to reduce the salts in the land by the growth of certain crops which take up a large proportion of mineral matter, but I have not been able to ascertain that much good can be thus effected. Sugar-beet and mangolds do appreciably reduce the salt content, but are hardly valuable enough to pay for such special cultivation and the limited irrigation-water; the best thing appears to be to grow salt-bush on the non-irrigated margin of such areas, if only to prevent the efflorescent salts from blowing on to the cultivated portion.

Let us now turn to the problem of land reclamation as it occurs in North-Western Europe. There are two main types of land that have hitherto been left waste, the peaty and the sandy areas. Of the peaty areas we can distinguish again between the low-lying moors bordering the lower courses of the great rivers; for example, in England near the mouth of the Trent, and the upland peat-bogs of which Ireland furnishes so many examples. They have these features in common—an excess of water, a deficiency of mineral salts, and, particularly in the upland bogs, a strongly acid reaction; but they possess great potential wealth in their richness in nitrogenous organic matter. It is in Germany and Holland that the methods of bringing into cultivation these moors have been most completely worked out; in Germany, for example, it is estimated that there are about five million acres of moorland, of which about 10 per cent. is now under cultivation. The reclamation process must begin by drainage, which may be carried out by open ditches, but is most satisfactorily effected by pipes, despite the greater cost. The water-table must be kept some 3 feet below the surface. In districts which afford a market for peat, as, for example, on the Teufelsmoor near Bremen, the reclamation often begins by cutting out the peat, the lower layer of firm peat being won, dried, and sold for fuel. The upper spongy peat can be used for litter, but some part at least must be thrown

back. Where the burning peat is thus extracted the excavation is in places pushed further until the underlying sand is reached, and enough of this is dug to spread over the reclaimed area to a depth of 4 or 5 inches and mixed by cultivation with the spongy peat. Even when the peat is not removed, pits are often made in order to sand the land, so great an improvement does it effect in the character of the crops. However, sanding is not possible everywhere, and there are great areas under cultivation where the reclamation begins with drainage, followed by the cultivation of the immediate surface without either sanding or the removal of the burning peat, which indeed are impossible over large areas, but are carried out by the owners of small farms little by little. Special tools are required: certain forms of disc-ploughs and harrows give the best results; heavy tools for large-scale cultivation by steam or electricity are furnished with broad roller-like wheels; even the horses must wear broad wooden shoes.

The next stage is the manuring, and it has only been the development of the artificial-fertiliser industry during the last half-century that has rendered the cultivation of this type of land possible. On the alluvial moors where the ground water has always been alkaline, the peat is rich in calcium and no treatment with lime and marl is necessary (the English fens afford an example of this type of soil), but on the true peat-bogs (Hochmoor of Germany) the manuring must begin with a good dressing of burnt lime, or, better, of marl or ground chalk. For meadows and pastures two tons per acre of lime, or twice as much of carbonate of lime, should be applied; the amounts may be halved for arable land. This must be followed by about 5 to 8 cwt. per acre of basic slag and an equal amount of kainit, which applications should be renewed in the second year, but then diminished in accord with the cropping. However, some phosphoric acid and potash salts must be continuously supplied, with occasional dressings of lime or chalk on the acid peaty areas. These latter also require in their earlier years nitrogenous manures, for the peat is slow to yield up the nitrogen it contains. The fertilisers should be nitrate of soda or lime, never sulphate of ammonia. The whole success of the reclamation depends on the use of these manures, as the peat in a state of nature is almost devoid of both phosphoric acid and potash; on the acid peats, again, normal growth is only possible after a neutral reaction has been attained by the use of lime or marl With this manuring it is found to be easy to establish a good meadow herbage in a very short space of time; it is not even necessary to get rid of the surface vegetation of *Erica* and other heath and bog plants. The manure is put on and the surface is worked continuously with disc-harrows and rollers, but never deeply; a seed-mixture containing chiefly red, white, and Alsike clovers, *Lotus uliginosus*, rye-grass, Timothy, and cocksfoot, is sown in the spring and soon succeeds in choking the native vegetation.

It is impossible to say what is the cost of the reclamation of moorland in this fashion; the big expense is the drainage and the construction of roads, both of which are entirely determined by local conditions. But of the value of the process when accomplished there can be no doubt. I have seen a case quoted from the 'Ostfriesische Zeitung,' where a piece of moor bought for 75*l.* was reclaimed and sold for 900*l.*; and, best test of all, one may see in places like the Teufelsmoor near Bremen, families living in comfort on thirty to forty acres of what was once merely wild moor with no productive value.

Of even greater interest in England is the reclamation of heath-land, which has of late years been proceeding apace in Germany. In this category we may include all land which owes its infertility to the coarse grade and low water-retaining power of the particles of which the soil is composed; the soil being at the same time as a rule devoid of carbonate of lime, and covered in consequence with heather and similar calcifuge plants. In England there exist extensive tracts of uncultivated land of this character in close proximity to the considerable populations, but the process of reclaiming such land for agriculture seems to have come to an abrupt conclusion somewhere about 1850, when the developing industries of the country began to offer so much greater returns for capital than agriculture. That land of the kind can be cultivated with success is evident from the mere fact that everywhere prosperous farms may be seen bordering the wastes, possessing soils that are essentially identical with those of

the wastes. These were brought under cultivation when labour was cheaper, often without calculation of the cost because the work was done piecemeal at times when the men would otherwise have been idle. Were any strict account to be framed, the reclamation probably did not pay its way for many years, and it has only become possible again because of modern advances in science and machinery. As examples of the type of land, I may instance the Bagshot Sands on which, in north Surrey, in Berkshire and Hampshire, and again in its southern development in the New Forest, lie so many thousands of acres of uncultivated heath. No systematic reclamation has taken place, but everywhere farms have been carved out on this formation, often by the industry of squatters, and within reach of London the vast supplies of town manure which used to be available have converted some of it into fertile land. The crystallisation of common rights into charters for public playgrounds, its growing appreciation for residential purposes, will now always stand in the way of the utilisation of most of the Bagshot Sands for agriculture, but further afield there are many areas of similar character. The Lower Greensand is perhaps equally discounted by its residential value, but on the Tertiaries of Dorset, the Crag and Glacial Sands of Suffolk and Norfolk—the brak, the Bunter Beds of the Midlands, lie many expanses of waste that are convertible into farming land, just as Lincoln Heath and much of the beautifully farmed land of Cheshire have been gained for agriculture within the past century. Equally possible is an attack upon the sandy areas, warrens or links, behind the sand-dunes on many parts of the English and especially the Welsh coasts; not all of them are wanted for golf, and many can be fitted for market-gardening. Of old the only way of dealing with such land was merely to clear it, burn the rubbish, and start upon the ordinary routine of cultivation, but for a long time on such a system the crops will hardly pay their way from year to year, and the permanent deficiencies of the soil in lime and mineral salts remain unrepaired. In Cheshire the enormous value of marl and bones in such a connection was early recognised; it has been the later discovery of the potash salts that renders reclamation a commercial proposition to-day. The method that is now followed is to begin by clearing the land of shrubs, burning off the roughest of the vegetation, and turning over a shallow layer in the summer, leaving the heathery sod to the killing and disintegrating action of sun and frost until the following spring. The manure is then put on—lime or ground chalk or marl as before, basic slag and kainit, and the sod is worked down to a rough seed-bed on which lupins are sown, to be ploughed in when they reach their flowering stage. The growth of the lupins makes the land, they supply humus to bind the sand together and retain moisture, they draw nitrogen from the atmosphere and with the phosphoric acid and potash form a complete manure for succeeding crops. Sometimes a second crop of lupins is ploughed in, but usually the land is put immediately to an ordinary rotation of rye, oats, potatoes, and clover. When the heath-land is divided among small tenants in an unreclaimed state, cropping often begins without the lupins, the necessary nitrogen being imported by nitrate of soda, but for years the land shows inferior results. Only the tenant can rarely afford to lose the year the lupin crop involves, and so great is the demand for land in Germany that the State finds it preferable to let the tenant reclaim than to reclaim for him, and charge him as rent the cost of the more thorough process. And now as to the finance of the operation: the reclaiming down to the ploughing in of the lupin crop costs from 5*l.* to 6*l.* an acre, the bare heath costs from 5*l.* to 7*l.* an acre, the reclaimed land after a few years' cultivation would sell at 20*l.* to 30*l.* an acre. Meantime the State has probably made a free grant for drainage, looking to get some interest back in increased taxation; the local authority has also made roads for which the increased rating due to a new agricultural community must be the only return. It is a long-sighted policy which will only find its full justification after many years, when the loans have all been paid off and the State has gained a well-established addition to its agricultural land and its productive population. In comparing English with German conditions there are certain differences to be taken into account—in the first place the work of reclamation will be dearer in England because of the higher price of labour, then the land will not be so valuable when won because the higher scale of prices for agricultural products enhances the price of land

in Germany. Next, I doubt, in view of the great industrial demand for men in England, if we have the men available who will bring to the land the skill and power of drudgery that I saw being put into these German holdings of thirty to forty acres in their earlier years of low productivity. Moreover, in Germany these heaths are generally bordered by forests, in which the small holder gets occupation for part of the year while his wife and children keep the farm going. For this, if for no other reason, afforestation and land reclamation and settlement should go on together. But, despite these drawbacks, I am still of opinion that the reclamation of such heath-lands is a sound commercial venture in England, either for a landowner who is thinking of a future rather than of a present return on his capital, or for the State or other public body, wherever the waste land can be acquired for less than 5*l.* an acre. The capitalised value of its present rental rarely approaches that figure, but the barrenest heath is apt to develop the potentialities of a gold-mine when purchase by the State comes in question. The map of England is so written over in detail with boundaries and rights and prescriptions that the path of the would-be reclaimer, who must work on a large scale if he is to work cheaply, can only be slow and devious. There are other possibilities of winning agricultural land even in England, from the slob land and estuaries, from the clays nowadays too heavy for cultivation; but the problems they present are rather those of engineering than of agricultural science. What I should like in conclusion once more to emphasise is, that the reclamation of heath and peat-land of which I have been speaking—reclamation that in the past could only be imperfectly effected at a great and possibly unremunerative expense of human labour—has now become feasible through the applications of science, the knowledge of the functions of fertilisers, the industrial developments which have given us basic slag and potash salts, the knowledge of the fertility that can be gained by the growth of leguminous plants. From beginning to end the process of reclamation of moor and heath, as we see it in progress in North-Western Europe, is stamped as the product of science and investigation.

MELBOURNE.

FRIDAY, AUGUST 14.

Discussion on Dry Farming.

(i.) *Dry Farming Investigations in the United States.* *By* Dr. LYMAN J. BRIGGS.—See Reports, p. 263.

(ii.) *The Ten-inch Line of Rainfall.* *By* Professor THOMAS CHERRY, *M.D.*, *M.S.*

The relative importance of Australia in regard to the future food-supply of the world is influenced to a very marked degree by its average winter temperature and the peculiar incidence of the rainfall throughout the southern third of the Continent. In these regions the term 'dry farming' has a different meaning from that accepted in the Northern Hemisphere, on account of the fact that our rainfall is almost exclusively of the winter type, and that the winter temperatures are high enough to keep the ordinary cereals growing steadily during these months. Consequently, before the dry summer sets in the crops have reached a sufficient degree of maturity to complete their ripening before the soil has become too dry to arrest all further growth.

Graphs were shown illustrating typical rainfall records in the region of the winter rains in all the States of the Commonwealth except Queensland and the Northern Territory. A brief comparison was made with the limited areas in other parts of the world which are similarly situated.

As a result of these conditions it may be said that in the southern parts of

the whole of Australia 'dry farming' does not begin until the 15-inch line of rainfall is passed, because the winter and the total rainfalls are nearly identical. The experience of the last fifteen years has shown :—

(1) That with the assistance of small amounts of soluble phosphates profitable crops may be grown on less than 10 inches of winter rainfall.

(2) Provided the land is fairly fertile rapid growth takes place in July and August, so that a considerable margin is available in autumn for early and late planting.

(3) The dry weather towards harvest-time materially reduces the risk from all fungus diseases in cereals.

(4) Wherever wheat can be grown peas may also be grown if necessary as an alternate crop.

(5) Evaporation in winter is comparatively small, and consequently by fallowing and other modern methods a payable crop is obtained on a lower rainfall than is the case in any other part of the world.

(6) The slight ground-frosts which often occur in the winter nights appear to stimulate the growth of the cereals when followed by ten hours of bright sunshine.

(7) The chief problem which has now to be solved is to devise methods by which large numbers of sheep and cattle can be profitably kept on the wheat farms in the 10-inch rainfall regions.

(8) Lands originally covered with scrub and producing very little grass have been proved to be very suitable for wheat. With the gradual advances in the numbers of stock kept on these farms permanent agricultural settlement is likely to extend well beyond the 10-inch line of rainfall.

(iii.) *The Soil-Moisture Problem in Western Australia.*
By Professor John W. Paterson, *B.Sc., Ph.D.*

The author said that a sufficient supply of soil-moisture was, practically speaking, the paramount factor in crop-production. This was true in the relatively moist climate of Great Britain; the fact was illustrated in an extreme degree in Australian agriculture. Seasonal variations were less marked in Western Australia than in the Eastern States, and a graph was exhibited showing the variations in wheat yields per acre of the various States since 1901. The effects of drought were not simply connected with the annual rainfall of a locality. This was a popular fallacy; but when a crop suffered from drought the result was contributed to by quite a number of factors. Among those he would mention—(1) the total annual rainfall, (2) its monthly distribution, (3) the rate of evaporation as from a free surface of water, (4) the effect of climate upon the transpiration ratio of the crop, (5) the amount of soluble salts in the soil, (6) the physical character of the soil, (7) the skill in cultivation of the farmer, (8) the selection of drought-resistant species and varieties of crop-plant. In regard to annual rainfall, the South-Western corner of the State averaged well over 30 inches, but on the Eastern fringe of the wheat-belt wheat could be successfully grown with a 10-inch rainfall, but the greater part of the wheat area had an average of 14 to 20 inches. To visitors these amounts would seem low. The monthly distribution, however, was highly advantageous, as from 70 to 80 per cent. fell between an autumn seed-time and harvest. The third factor, viz., rate of evaporation, tended, however, against success, and data were quoted from the Commonwealth Weather Bureau showing that the annual loss by evaporation in the wheat-belt ranges from 60 to 80 inches of water, as against about 20 inches in the South of England. In England therefore the annual evaporation would amount to about two-thirds of the annual rainfall, while in the chief farming districts of Western Australia it was from four to six times greater than the rainfall. Closely connected with this in some, but not all, of its contributing causes was the lower efficiency of water to the growing crop, as indicated by the amount required to produce a given weight of dry plant substance. The transpiration ratio was indeed less a function of the kind of crop (speaking of the common crops) than a function of the climate, and the author quoted from experiments he had carried

out showing that on land of moderate fertility a ratio of 600 to 700 would be required for the wheat areas. This was roughly double the English ratio. Again, as regards soluble salts, the drier areas commonly held a slightly higher percentage than British soils, and while in Western Australia 'alkali' rarely of itself caused infertility, his experience of alkali lands, which he had investigated for the Victorian Government, indicated that such salts increased the liability of crops wilting. On consideration they would expect this. Again, the physical character of the soil had an important effect, and the sandy character of much of the western lands gave it an advantage over the heavier soils in a dry season. This was contradictory to his experience in the English Midlands with a 32-inch rainfall. Fifteen inches of rain absorbed by the surface five feet of soil would add something less than 20 per cent. of water calculated on the dry soil if it were absorbed without loss. But the annual rainfall was spread over several months, and the fact seemed to be that with a 15-inch rainfall the sandy soil could hold all the rain which fell, and the greater absorbent power of the clay soil was then of no advantage. It was indeed a disadvantage, as the finer-grained soil could not yield up so much of its absorbed water before wilting set in, and in the drier seasons and districts the 'sand plain' gave superior results to the forest land. In regard to cultivation methods, the author quoted figures from his experiments showing the large saving of soil-moisture by early cultivation and maintaining a soil mulch. The water saved would usually equal from 5 to 7 inches of rain in the surface five feet of soil. In Western Australia good results from fallowing were more easily obtained than in Victoria, where the more frequent summer rains tended to cake the surface, rendering fresh working of the land necessary. The water saved showed itself in the crop yields, and the results of a Kellerberrin farmer last season, showing 17 bushels on sand plain fallowed, and 5 bushels on similar land ploughed from stubble, could be regarded as typical under a 12-inch rainfall. The British farmer did not sufficiently realise the use of the soil mulch in protecting his winter-ploughed lands from the drying winds of spring. Lastly, as to the selection of drought-resistant plants, much had been done through acclimatisation, selection, and cross-breeding, but a careful analysis of the various factors which in wheat constituted drought-resistance remained to be carried out before they could claim that plant-breeding for this object was placed on a scientific basis. Under the dry conditions of Australian wheat-growing a safe yield rather than a heavy yield was the primary consideration. This necessitated the selection of early or middle-early varieties, thin seeding, and in the great majority of cases the non-use of nitrogenous manures.

(iv.) *The Capillary Power of Soils. By* HEBER GREEN, *D.Sc.*

The conventional mechanical analysis supplies data about the sizes of the particles of the soil; the information actually required concerns the behaviour of the soil with respect to the movements of air and water therein. These latter are dependent on the sizes and distribution of the free spaces between the particles and only indirectly on the sizes of the particles.

This suggests a direct measurement, if possible, of the factors determining these physical characters and conditions of the soil, and the magnitudes to be considered are :—

S, the pore space, expressed as a fraction of the total volume of the soil; and θ, the water-content, similarly expressed. θ/S is then the fractional saturation of the soil.

$P\alpha$ and $P\omega$, the permeabilities to air and water. Incidentally the ratio of these two gives us an indication of the amount of colloidal matter present in the soil and of its tendency to swell when wet.

K, the capillary power. This taken with the previous factors gives a measure of the rate at which water will percolate from a wet to a dry region in the soil.

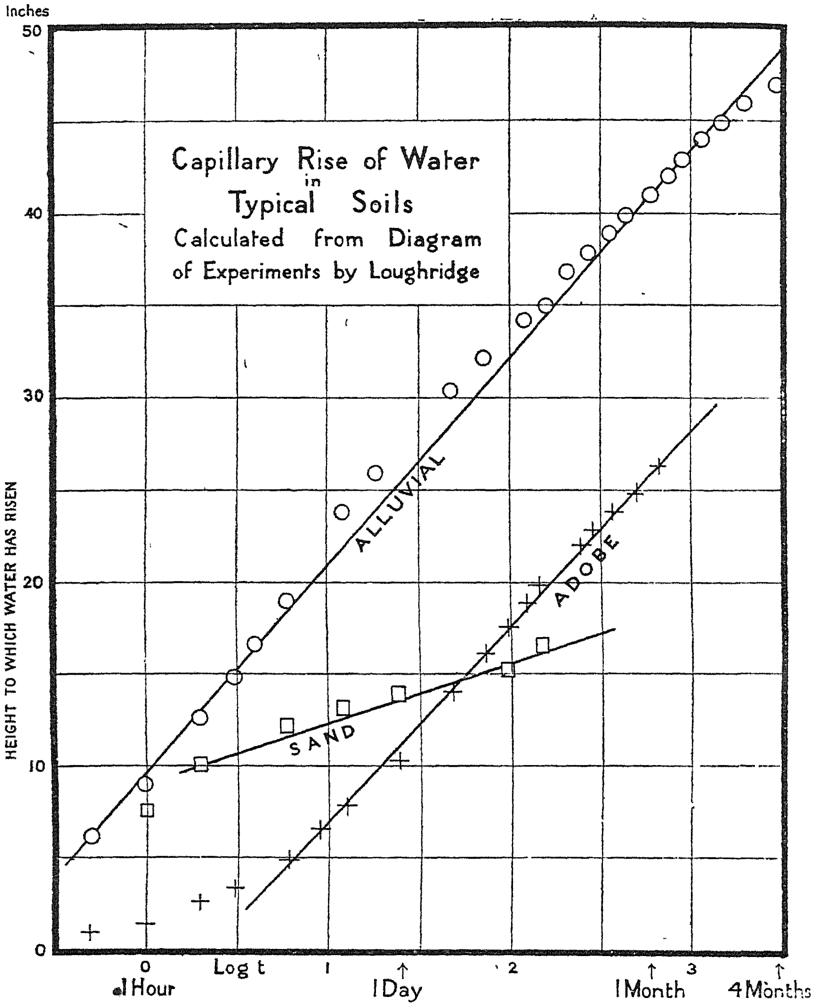
These factors (S, θ, P, and K) have been previously defined and methods for their measurement described.[1]

Of these S, θ, and P are simple properties with obvious physical meanings, but K (the capillary power) is of a more complex character and may be defined as the

[1] Heber Green and G. A. Ampt, *Jour. Agr. Sci.*, 1911, 4, p. 1.

pull per unit area which the soil can exert on a layer of water in contact with it. This capillary power will obviously depend on the water-content of the soil; when $\theta/S=1$, then $K=0$; the maximum value of K being reached when $\theta/S=0$, *i.e.*, when the soil is dry.

The value of K between any given limits of θ/S becomes of practical importance, for under field-conditions soils are rarely absolutely dry or completely saturated



and the water-movements with which we are most concerned are from relatively moist to relatively dry sections.

This capillary power is due to the surface-tension effects produced by the attraction between the walls of these capillary pores and the water in the soil, and may be most conveniently studied by considering a vertical column of soil with its lower end placed just in contact with a free surface of water. It has previously[2] been

[2] *Loc. cit.*

shown that such a column of soil will behave (statistically speaking) as a bundle of capillary tubes, varying from a maximum radius depending on the size of the largest soil-grains down to others extremely minute. The water will rise in each capillary to a height inversely proportional to its radius, equilibrium being rapidly attained in the larger tubes; but, as the frictional resistance varies inversely as the fourth power of the radius, the rate of rise in the smallest tubes will steadily slacken but will not absolutely cease within any finite time.

This rise without limit is in conflict with the generally accepted opinion, and Hilgard[8] quotes a series of experiments by Loughridge, in which the final heights recorded (after several months) are regarded as maxima for the soils concerned. The rate of rise in his experiments may be shown to be inversely proportional to the time; i.e., $dh/dt=k/t$ or $h=A+B \log. t$. From the examples illustrated in the graph in the accompanying diagram it is clear that any apparent limit to h within a reasonable time or variation from a linear function can only be due to initial disturbances or other accidental errors.

With a view to a further and more accurate investigation the author has arranged a laboratory draught-cupboard so that it can be maintained at a constant temperature for several months at a time.

Experiments have been carried out on the rate of rise of water in soils of different types; and the dependence of K (the capillary power) on S and θ/S and on the sizes of the soil-grains has been investigated.

(v.) *Flax as a Paying Crop.* *By* C. P. Ogilvie.

Flax destined for fibre has to be cultivated on different lines from that of flax-seed or linseed (as it is usually called). Should seed be required, flax is sown thinly, about a bushel and a half per acre—by planting thinly the stem has a chance to branch out and flower.

If fibre is the chief object the seed is planted closer—about two or two and a half bushels per imperial acre—the result being the drawing up of the stalks with little tendency to branch.

The total of the last available figures shows that the world's flax crop (including Russia for 1911) was grown on over four and a half million acres, which produced over 800,000 tons.

In 1912 Russia alone had 3,832,056 acres under cultivation, which produced 817,871 tons, and out of this she exported 345,216 tons, realising 11,432,954*l.* To the United Kingdom she sent 68,500 tons, valued at 3,474,187*l.*

In Ireland there are nearly 1,000,000 spindles at work, over 7,000,000*l.* are sunk in mills, machinery, etc., and 5,300,000*l.* are constantly locked up in manufactured goods; 3,300,000*l.* are annually paid to Irish fibre-workers.

It would seem, therefore, that the agricultural part of the business is assured, but it is not so.

In England and Scotland flax has almost ceased to be grown, and the acreage in Ireland has been reduced from 301,693 in 1864 to 46,921 in 1912. The acreage cultivated in 1913 was, however, increased.

Within the last two or three years great strides have been made in our knowledge, and Governments are assisting colleges and others in studying the history and habits of flax.

By constant attention and selection longer straw which will not branch until full height will be secured. A steady growth produces best fibre, and small clean stems will produce the finest filaments. The root itself has no fibrous tissues.

The fibres are surrounded by pectose, and lie in bundles containing varying numbers of filaments.

The process of separating fibre from the boon and rind has engaged many minds. Artificial means and chemistry have been employed without end. Recently a new method has been tried upon the principle of solvency under pressure, and has proved highly successful.

The old process of retting and scutching was explained.

[8] *Soils*, p. 205.

Interest in the flax-fibre industry has entered into a new phase of existence, with a brighter horizon.

Given suitable land, good seed, careful supervision, scientific degumming, and improved scutching, there is no reason why farmers should not devote part of their land to flax for production of fibre. It should return a better result financially and give greater employment than any other crop usually grown.

TUESDAY, AUGUST 18.

The following Papers were read :—

1. *Methods of Milk Recording. By* ALEXANDER LAUDER, *D.Sc.*

In this paper a short account was given of the methods of obtaining the milk records of dairy cattle as carried out in Scotland and Ireland. In Scotland the work has been practically confined to the Ayrshire breed. A scheme has been in operation since 1903, but in the earlier years the number of herds under inspection was comparatively small. The work is now under the direction of the Scottish Milk Records Committee, a representative body in receipt of an annual grant from the Development Fund. In 1914 this grant amounted to 2,000*l*. The number of cows under inspection has increased rapidly from year to year, and during the present year has reached 25,000.

The work is carried on through local societies consisting of twelve to twenty-four members, so that the work of each society is sufficient to take up the whole time of a recorder. The weighing and testing may be done every fourteen, twenty-one, or twenty-eight days, according to circumstances, an interval of twenty-one days being the most common in Scotland. The recorder arrives at the farm in the afternoon, weighs, and determines the percentage of fat in the evening milk and the morning milk next day. All the testing and weighing is done by the recorder, the farmer being only asked to supply details as to feeding, times of calving, &c. A copy of the record is left with the farmer, and a copy forwarded to the offices of the Central Committee.

Finance.—The expense of carrying on a local society may be put at about 80*l*. per annum. Part of this expenditure is met by a grant from the Central Committee, and the remainder is apportioned between the members. In some societies the members are charged so much per cow. The cost per cow is from 1*s*. 9*d*. to 1*s*. 10*d*. per annum, and each member is charged on a minimum of forty cows.

Results.—The systematic keeping of records of the yield of milk and the percentage of fat has led to the gradual elimination of the less productive cows from the herds. In this way the average yield of the herds has been greatly increased, and also their value, especially for export purposes. In some herds the average annual yield per cow has been increased by 100 to 200 gallons in six to eight years.

The increase in the value, since the beginning of the scheme, of Pedigree (Milk Record) Ayrshires for export purposes is estimated at about 50 per cent.

In this connection the importance of the sire being descended from a dam of good milking qualities has been proved by experiment, and cannot be too strongly emphasised.

Classification of Cows.—For purposes of comparison the yield of milk is calculated to the equivalent amount containing one per cent. fat.

In judging cows at cattle shows the more rational method of taking into account the milk-yielding capacity of the cow is gradually superseding the former method of depending solely on appearance. Three classes are now commonly adopted :—i., For cows giving over 1,200 gallons; ii., for those over 1,000 gallons; iii., for those over 800 gallons.

Irish Method.—The milk recording and testing in Ireland are carried out under a scheme of the Department of Agriculture and Technical Instruction. Under this scheme the cows have first to be inspected and approved. The farmer weighs the milk on one definite day per week, and his herd and records are open

to inspection at any time without notice. The Department's inspector checks the farmer's weighings, and takes samples of the milk at intervals for analysis. Approved cows, of proved milk-yielding capacity, are then eligible for entry in the Department's herd book.

A short account was given of Gavin's statistical inquiry into the accuracy of estimating a cow's milking capability by her first lactation yield [Gavin, 'The Interpretation of Milk Records' (*Journal Royal Agricultural Society*, 1912, p. 153); 'Studies in Milk Records' (*Journal Agricultural Science*, 1913, vol. v., parts 3 and 4)].

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2. *Milking Machines in Victoria.* *By* R. T. Archer.

There are about fourteen different makes of milking machine in this State, and as far as can be ascertained 2,000 farmers have been supplied with machines equal to 6,000 single machines or pulsators. Some of these have been put out of use for various reasons considered below. One of the principal advantages in connection with machine milking is that it makes a farmer practically independent of labour, which is a difficult problem in this country.

When the machines are handled properly by those who take an interest in them they give thoroughly satisfactory results; especially is this the case with heifers first broken in to the machine. It is found also that the milk keeps satisfactorily. That this should be the result with proper handling is proved by the experience at the Lady Talbot Institute. On the other hand, it is difficult, almost impossible, to persuade the average dairy-farmer to exercise the necessary care in cleansing the machines, and when this is neglected the quality of the product suffers.

Types of Machines.

All the machines but one in use in Victoria are worked on the vacuum principle, which is produced either by pump or by a steam-ejector. The systems in use are the bucket and the conduit or tank. In the conduit system the milk is conveyed from the teats through pipes to a tank in any convenient place, but the pipes become an additional menace in careless hands. They are of brass or gun-metal with polished surface inside. Experiments are being made with strong clear glass tubes to replace the metal. If these prove satisfactory it will be easy to see if they are clean. In this system various valve devices are used to provide automatic release of the milk so that the vacuum may be sustained.

Another type of apparatus used for milking, which on account of its apparent cheapness and simplicity is likely to find favour with the uninitiated, consists of four ordinary milk-tubes or teat-syphons with rubber tubes attached to convey the milk to the buckets.

Many reliable users of the milking machine claim that with the machines the cows never have sore teats, and if used on a cow with sore teats they rapidly heal and do not bleed as they do when milked by hand. Some claim that contagious mammitis is more likely to spread with machines, but this only applies to the careless man.

Cost of Upkeep.

This varies according to care bestowed, but under proper treatment it may be put down at about 1*l.* per machine per annum. Aluminium is largely used now in the teat-cups, and many of these appear to corrode rapidly at the top and bottom. Some attribute this to milk, but it is more probably due to the soda used in cleansing. It is questionable if aluminium is suitable for this purpose. Light gun-metal or brass cups nickel-plated appear to stand better.

The Sanitary Aspect.

The greatest problem in connection with the milking machine as it presents itself in this country is with regard to sanitation. The difficulty is to impress users with the necessity of properly cleansing the machines as soon as possible after using. The experience gained through the Lady Talbot Institute goes to prove that with proper care milk can be produced giving an exceptionally low bacterial count.

Lady Talbot Milk Institute.

Table showing number of micro-organisms per cubic centimètre (machine milking) :—

—	911	1912
February	9,000	5,300
March	29,600	21,200
April	25,400	31,300
May	3,600	11,600
Average	23,800	18,700

Table showing average of micro-organisms per cubic centimètre after deleting the figures for the sample yielding the highest count each month. (This table gives a better idea of the bacterial condition of the bulk of milk supplied by the Institute.)

—	1911	1912
February	4,400	2,500
March	14,500	4,100
April	20,600	8,000
May	3,600	9,900
Average	15,100	5,600

Experiments conducted at the farm proved the superiority of the machines over hand milking as regards cleanliness.

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3. *Trials of Milking Machines.* *By* Dr. R. Stenhouse Williams, J. Golding, *and* James Mackintosh.

At the trials of milking machines arranged by the Royal Agricultural Society of England in 1913, the chemical and bacteriological tests were conducted by the authors. Eleven machines competed, and the paper discussed the various lines of development along which future progress may take place.

At the outset it may be stated that the Committee excluded syphon machines on the ground 'that they were rightly considered by the Society to be injurious to the cows.'

There remained then two types of machine :—

A. Pressure machines, those in which an attempt was made to simulate the process of hand milking, and

B. Suction machines, those in which suction in one form or another was employed.

Of the former three competed. The bacteriological results were as follows :—

O	P	Q
675	4,603	5,161,

which represents the average bacteriological content per c.c. during the trials.

Remarks on Pressure Machines.

O. Squeezing the teats from above downwards. No friction on udder. Milk caught in open pail.

P. Squeezing of teats by rubber plates associated with adjustable shields which massaged the udder during milking, thus dislodging hairs and dirt particles. Open bucket underneath the udder.

Q. The milk was expressed by pressure only and conveyed by short channels to an open tray, thence by a tube to the receiver which is suspended underneath the cow. As it enters the receiver the milk is strained.

Remarks on Suction Machines.

The results obtained with these machines depend, firstly, on the defects in the machines themselves, and, secondly, on the care and skill of the operator. It was not always possible to differentiate between these, but the following instance may be given as indicating the effect of want of care in this direction.

A (average bacteriological count 3,103 per c.c.) compared with D (average bacteriological count 1,579 per c.c.).

A was a better machine but not so well cleansed.

Again, if we consider four of the suction machines in all of which reasonable care was taken in the cleansing, we find that the average count varied from about 2,000 to about 4,000 organisms per c.c. On the other hand, the two machines in which the cleansing was undoubtedly indifferent had average counts of 41,419 and 12,384. The bacterial content in the machine giving 12,384 was mainly due to inefficient cleansing of the machine. In the machine giving 41,419, insufficient cleansing, excessive length of rubber tubing, and leakages contributed to the high count.

It appears, therefore, that suction machines, as exhibited in this trial, depended to an unreasonable extent on the personal equation, and demanded an amount of intelligence that cannot be expected from the average cow-man.

The results seem to indicate that some type of pressure machine milking directly into a covered can might give the most effective bacteriological results in the hands of an ordinary worker.

The suction machines with their tubing and fittings require a cleansing between each milking, which almost amounts to bacteriological sterilisation, if really good results are to be obtained. The absence of the means to effect this on many farms, and the lack of training in those who have to perform the work, render a plea for the simplification of the machine specially cogent.

4. *The Results of Milk and Dairy Supervision in Victoria. By* DR. S. S. CAMERON.

5. *Milk and Butter Records of Pure-bred Cows in Australia, with Special Reference to the Australian Breed of Milking Shorthorns. By* M. A. O'CALLAGHAN.

This paper showed what the Government of New South Wales and the breeders of pure-bred dairy cattle are doing towards obtaining the records of all pure-bred cows in the State.

Records were given for Australian dairy shorthorns, and also a brief history of the formation of this breed.

Records were also given for Jerseys and Guernseys.

Climate and Food Conditions in relation to Composition of Milk.

The question of the effect of extreme periods of drought during which time cows receive no green food was referred to as affecting the solids not fat in milk.

The question was also raised as to the effect on the percentage of fat in milk of almost continual sunshine and absence of rainy weather coupled with good food conditions, such as prevail on the irrigated lands of Yanco district, New South Wales.

Milk and Butter Records.

Shorthorns (Australian type).	Butter lbs.	Milk lbs.
'Melba III.' for 9 months	585	13,818
,, ,, 12 ,,	653	15,238
'Champion III.' ,, 9 ,,	563	10,299
,, ,, 10 ,,	574	10,500
'Camelia II.' ,, 9 ,,	446	10,366
,, ,, 12 ,,	524	12,039
'Lily III.' ,, 9 ,,	580	14,742
,, ,, 12 ,,	689	17,599

		Butter. lbs.	Milk. lbs.
Jerseys.			
Hordern's 'Ledas Snowdrop' (imp.)	for 7 months	518	8,079
Gollan's 'Winsome'	,, 9 ,,	481	8,106
,, 'Bessie'	,, 9 ,,	454	8,134
Macdonald's 'Coomassie'	,, 9 ,,	497	8,363
,, 'Madeira 8th'	,, 9 ,,	482	6,685
,, ,,	,, 12 ,,	616	8,348
Miss Walker's 'Lady Capture'	,, 9 ,,	452	6,788
,, ,,	,, 10 ,,	482	7,277
Guernseys.			
*Perry's 'Mignotte 7th' (imp.)	for 9 months	331	5,786
* ,, 'La Colombe' (imp.)	,, 9 ,,	364	6,598
Kinross' 'Merton Margaret 2nd' (imp.)	,, 7 ,,	455	7,109
N.S.W. Government's 'Calm 2nd'	,, 41 weeks	503	7,548
,, ,, 'Parsons Red Rose 1st' (imp.)	,, 51 ,,	452	6,999

* Cows marked thus were only on their second calf.

6. *Preliminary Note on Wool Inheritance.* *By* P. G. Bailey, *M.A.*

This paper dealt with the methods employed in the experiments made at Cambridge on the question of the 'Inheritance of Wool Characters,' and the results so far obtained from these experiments.

A cross was made between two Merino rams sent us by the late Mr. Charles Harper, of Western Australia, and twenty Shropshire ewes. Thirty-one F_1 rams and forty-one F_1 ewes were obtained from this cross. An F_1 ram was mated to the F_1 ewes, and from these we have now got thirty-three F_2 rams and forty-seven F_2 ewes, but of these F_2 sheep only six rams and eight ewes have been shorn.

The methods employed in this investigation were the following:—

(1) Each sheep was given an earmark number in order that a complete pedigree should be kept.

(2) At shearing, small samples were taken from the two shoulders, neck, belly, and britch. The fleeces were then given the number of the sheep from which they came, were weighed and sent to Professor Barker at the Technical College, Bradford. They were there sorted into the commercial qualities.

(3) The commercial qualities apparently depend upon a large number of factors, each of which is possibly independent in its inheritance. These factors have been stated to be lustre, uniformity in length, waviness, and, most important of all, average diameter of fibre. Consequently it became necessary to analyse these factors separately. With Mr. F. L. Engledow's help, a microscopical investigation has therefore been made into these characters, especially as regards average diameter of fibre.

Results so far obtained:—

(1) Range of qualities shown by Bradford sorting:—

Merino rams	Quality	64^s
Shropshire ewes	,,	54^s–50^s
F_1 rams	,,	60^s–44^s
F_1 ewes	,,	60^s–50^s
F_2 rams	,,	60^s–54^s
F_2 ewes	,,	60^s–54^s

There is, in fact, a high range of variation in the F_1 generation, but the great bulk of the F_1 sheep are of a quality intermediate between those of its Merino and Shropshire parents.

(2) No accurate investigation has yet been made into the amount of grease in fleeces, but it was seen that the F_1 generation were intermediate in this respect between the two parents.

(3) The microscopical investigation of the average diameter of the fibres points to the fact that the great bulk of the F_1 sheep are intermediate as regards this character.

It has incidentally been shown that in order to obtain a probable error of less than 3 per cent. of the average of any sample it is necessary to take 160 measurements of that sample.

(4) There is a large variation in the range of the weights of the F_1 fleeces.

(5) The F_1 generation are also intermediate as regards the number of waves per inch.

7. *Size Inheritance in Poultry.* *By* P. G. Bailey.

WEDNESDAY, AUGUST 19.

Joint Discussion with Section G on Irrigation.

(i.) *Irrigation Works in Italy.*[1] *By* Professor Luigi Luiggi, *D.Sc., M.Inst.C.E., President, Italian Society of Civil Engineers.*

The average tourist who visits Italy and admires the splendid orange-groves round Sicily and Calabria, the industrial flower-gardens of the Ligurian Riviera, the luxurious vegetable-gardens and orchards of Tuscany and Campania, or the extensive green meadows of exuberant trefoil and lucerne of Lombardy and Lower Piedmont—if he has any tinge of poetry in his veins—will be apt to raise a hymn of praise to Providence for bestowing upon Italy such great blessings, and forget the industry of its inhabitants accused of the sins of 'dolce far niente.'

And truly Italy has been greatly favoured by a mild climate with plenty of sunshine—although even in excess in some parts; but beyond this, Providence has not done much more than for any other nation of Southern Europe, if it were not that it has also given to Italy a very hardy race of people, full of resources, very thrifty, content with little, and ready to till the land cheerfully from dawn to dusk in the hope of getting good crops, notwithstanding the numerous drawbacks of a rather poor soil, of a very irregular rainfall—in excess during the winter months, when it causes inundations, and nearly absent for five to seven months of the warm season, during which a fierce sun would scorch the land and dry up all vegetation if the industry of the Italian farmer did not overcome these natural drawbacks by means of a rational system of irrigation.

And, in fact, the prosperity of agriculture in the regions just mentioned—which are the most prosperous in Italy—is due exclusively to the incessant work of men who, far from enjoying much 'dolce far niente,' have applied, and are extending continually, the art of irrigation, which in Italy dates back from the time of the Etruscans, and has reached great perfection in our days.

Without irrigation, the rich orange-groves, the bountiful orchards and vegetable-gardens, which give such valuable products for exportation to Central Europe and North America, could not exist, and the land would give but a scanty revenue to its owners; but especially the luxurious and extensive meadows of the valley of the Po—which are intensely green all the year round, and give even seven or eight crops of fodder per year—could not exist, and barely one or two cuttings of grass could be raised without the help of irrigation.

It is the art of the hydraulic engineer and the intelligence and perseverance of the agriculturist that, by regulating the natural water-courses, impounding the water in reservoirs, or raising it from the subsoil or from the natural streams, and then distributing this water intelligently over the land at the proper time—that is, by scientific irrigation—have transformed the waste sandy plains of Piedmont and Lombardy into the most prosperous meadows of Europe, and made the orange-groves around the Tyrrhenian coasts so plentiful and beautiful as to cause Goethe to give to Italy the name of 'the land where the orange blooms.'

[1] Published in *Engineering*, September 18, 1914.

As the climatic conditions of Australia are very similar to those of Italy, it may be interesting—and it is hoped useful—to the citizens of the Commonwealth to know how Italians manage to get the best out of the natural conditions of their native land, which, owing to the prosperous state of agriculture from time immemorial—which leaves a good surplus for improvements and comfort—has made Italy the land of music, of poetry, and of arts.

After this introduction, showing that irrigation is the principal factor of the advanced state of agriculture, and the principal source of revenue for the Italian nation, the author described the different ways of getting water for irrigation, and how it is distributed over the cultivated fields.

The Cost of Water.—When only small quantities are required, as for the orange-groves and flower-gardens, the water is generally raised from the subsoil—at the foot of the hills or round the coasts—either by very primitive means such as water-buckets (*cicogne*) moved by men, or *norias*, or rosary-pumps moved by animals, as in Southern Italy, or by small but very modern centrifugal pumps moved by oil or electric motors, used especially along the Ligurian Riviera and in many parts of the valley of the Po, where hydro-electric plants are very common.

The cost of the water raised electrically—especially during the daytime, when the electric current is distributed at lower rates than at night—varies from 0·10 to 0·25 franc per cubic metre (from $4\frac{1}{2}d.$ to $11d.$ per 1,000 gallons), and it is considered not dear, for if raised by animals or, worse still, by men, its cost would be respectively eight to seventeen times higher.

Nevertheless the products grown with irrigation realise such high prices that this expenditure is justified, and also a very fair profit is left to the growers of oranges, early vegetables, and flowers, which find a ready market in Central and Northern Europe, especially during the winter months. The revenue of a good orange-grove varies from 2,000 to 3,000 francs per hectare (36*l.* to 54*l.* per acre) per year.

Huge Reservoirs.—For irrigation on a large scale—that is, for fairly large farms of some 50 to 100 acres in extent, where ordinary vegetables, fruit-trees, vines, olives, &c., are cultivated—this price of water would be prohibitive, and, besides, the quantity would be insufficient. Then recourse is had to collecting the rainfall—which on the average varies from 36 inches in North Italy to 15 inches in the South—by storing it up in reservoirs. These vary from the modest cistern of some few hundred cubic metres capacity, sufficient for the horticulturist, to large artificial lakes of many million cubic metres formed in some valley of the Alps or of the Apennines by high dams, built either of earth, rock-fill, or masonry, the last being generally preferred.

There are already many large reservoirs, especially in Northern Italy, such as the Lagastrello, Brasimone, Gorzente, Devero, Adamello, and others, but the largest of all is now in construction in Sardinia, across the River Tirso. The dam, of masonry, is 55 metres high (179 feet), and is of gravity section. It will impound 350 million cubic metres (12,250 million cubic feet) of water —so that it will be the largest in Europe—sufficient to irrigate from 20,000 to 30,000 hectares (about 50,000 to 80,000 acres) of land capable of being cultivated for early vegetables, fruit, oranges, olives, vines, and such good-priced products.

Several other dams are soon to be built in Southern Italy, the most important being on the rivers Bradano, Sila, Simeto, and Fortore. The latter will be 75 metres high (243 feet), and will impound 410 million cubic metres (14,350 million cubic feet) of water and irrigate about 100,000 acres in the fertile plains of Apulia.

The water from all these artificial lakes is generally used first for motive power, in some hydro-electric installations—which in Northern Italy are very plentiful, and this helps much in lowering the price of the irrigating water—and afterwards it is distributed by means of canals to the different farms, at prices varying from about 0·005 to 0·01 franc per cubic metre (from $\frac{1}{4}d.$ to $\frac{1}{2}d.$ per 1,000 gallons), or at the 'lump sum' or 'annual rate' of from 80 to 120 francs per hectare (1*l.* 10*s.* to 2*l.* 10*s.* per acre per annum).

These prices, however—although quite reasonable in semi-arid regions, where a timely irrigation may save the crops from total failure in a year of drought—are still too high for ordinary irrigations, especially of meadows, and besides,

for very large extensions of land, the quantity of water that can be impounded in an artificial lake is always comparatively small.

Canals.—So, when large quantities are required, the water is obtained from rivers, fed, generally, by some natural lake, like the rivers Ticino, Adda, Oglio, Mincio, or by some glacier which, melting in the summer season, acts practically like a lake of frozen water; in this condition are the rivers Tanaro, Po, Dora, Orco, Adige, and many others.

The engineering works consist of a submergible dam of very substantial masonry, built across the river, and capable of raising the level of the water to that of the country to be irrigated; of some controlling sluices at the canal head; and of a main canal, with lateral distributing ditches, provided at their intake with some apparatus for measuring the water to be delivered. Generally, the 'Cipeletti Weir' or some such over-fall weir is used. No mechanical meters are adopted, except for very small deliveries.

The price of this canal water varies from 20 to 45 francs per hectare per year (8*s.* to 1*l.* per acre).

Many of these irrigation canals date back from the Middle Ages. For instance, the 'Naviglio Grande' was built in the twelfth century, and is used also for inland navigation—in fact, it is a feature of these canals called 'Navigli' to serve both for irrigation and navigation purposes. The 'Naviglio Grande' is about 50 miles long, and has a capacity of 55 cubic metres (2,275 cubic feet) per second; and in order of date come the 'Muzza' with 60 cubic metres, the 'Cremona' with 30 cubic metres, and scores of smaller ones.

Of the canals of modern times—that is, built during the last fifty years—the most interesting, also from the point of view of the engineering features, are the 'Cavour' canal with 110 cubic metres discharge (3,850 cubic feet) per second, the 'Villoresi' with 44 cubic metres (1,500 cubic feet), the 'Marzano' with 30 cubic metres (1,050 cubic feet), the 'Veronese' with 15 cubic metres (510 cubic feet), and the 'Tagliamento' with 17·5 cubic metres (600 cubic feet) per second. They are really models, both from the engineering point of view and the perfection of their administration; so much so, that many engineers come from all parts of the world to study them.

The largest and longest of all is the 'Cavour' canal, with a discharge capacity of 110 cubic metres (3,850 cubic feet) per second, and a development of fully 1,000 miles, including its branches. It was built in 1855-65 by a private company that failed, and was taken over by the State.

This canal, the most important in Europe, was the means of transforming an almost barren region of 250,000 acres of sand and gravel—useful only for growing timber and bushes—into the most fertile rice-fields and meadow-land of Italy, where the best Parmesan and Gorgonzola cheeses are produced. A still larger canal is about to be undertaken, the 'Emiliano' canal, with a capacity of 300 cubic metres (10,500 cubic feet) per second, 120 miles long, and estimated to cost 12,000,000*l.*

Results of Irrigation.—The author described, with the help of lantern slides, the most salient engineering features of some of these canals, *i.e.*, their head-works—one of them at the 'Ombrone' inlet is capable of receiving 600 cubic metres (21,000 cubic feet) per second—and the numerous aqueducts and syphons over and under existing canals or rivers; pointing out that the irrigation canals of Italy carry the life-blood of the national agriculture. He described also how the water is applied to the crops, the 'rotations' or periods of irrigation used according to the nature of the land, its permeability, and the crops to be raised; concluding with the results obtained by irrigation, which are most satisfactory from the agricultural point of view, as the rent of the fields is more than doubled or trebled by irrigation. From the financial point of view of the Canal Administration, however, with very rare exceptions, the results are not so satisfactory, and in fact are generally disappointing. It is not sufficient to build a canal carrying a large volume of water, it is necessary to sell this water—that is, find the farmers ready to use it—and provide to pay for the original cost of the canal and its ordinary expenses. But in order to use the water, it is necessary for the farmers first to prepare their own distributing ditches, then to level their fields properly, and learn how to apply the water to the land at the moment, and in the proportion most convenient; to decide which crops are

the most profitable in regard to the different markets, and—where the land is not very permeable—it is also necessary to prepare drainage ditches in order to get rid of the surplus water that otherwise might damage the vegetation or produce an excess of parasitic plants. All this requires experience, time, and capital, and thus the Administration of the irrigating canal is not in a condition to sell all its water for many years.

In the best conditions it takes from twenty to thirty years—and sometimes even more—to dispose of all the water of a large canal.

For instance, the 'Marzano' canal, which crosses the province of Cremona, where irrigation has been adopted since the Middle Ages, and all the distributing ditches were already made when the main canal was built—in fact, its function is that of increasing the flow of the older irrigation canals—needed fully thirty years before all its cubic metres per second of water were disposed of, although the conditions were most favourable. The 'Villoresi,' also in a region where irrigation is pretty well developed, after forty years has not yet disposed of all its water, and the financial conditions of its administration are far from being prosperous.

The State's Help.—This is the reason why the State considers it is its duty to help all these undertakings. Irrigation puts under cultivation large tracts of land of very little value, and in places almost sterile, and part of the population that now emigrates abroad can thus find useful employment in the cultivation of this land, otherwise nearly useless, and thus increase the national wealth.

Italy has an increase of population of almost one million souls per year, and some 500,000 to 600,000 people are obliged to emigrate, especially to North America, or Central Europe, while some 100,000 go to Argentina, and 50,000 to other countries round the Mediterranean.

To moderate this exodus, which is not beneficial to the country, the State encourages irrigation by granting a subsidy of three per cent. per year for a period of ten years on the capital spent in the construction of the main canal and its principal branches, two per cent. per year for the following ten years, and one per cent. for another period of ten years. Then the subsidy ceases, but in the meantime these subsidies, capitalised at five per cent., represent already about thirty-five per cent. of the initial expenditure. But if the canal is arranged in such a way as to help to control the flood-water of rivers—as when impounding reservoirs are also built—then some subsidy is also granted on the capital in the proportion of ten per cent. to thirty per cent. of the expenditure. For instance, for the Tirso reservoir and canal, estimated at about 20 million francs (800,000*l.*), the State, besides the usual grants, pays three million francs (120,000*l.*) for the beneficial effect on the *régime* of the river, and grants a yearly subsidy of 150,000 francs (6,000*l.*) for fifty years for the canal, provided that the price of the water for irrigation is not more than 32 francs per hectare per year (11*s.* per acre). After sixty years all the works become the property of the State.

The conclusion, based on Italian experience, is that irrigation is very beneficial to the individual farmer, when he can get the water by paying 30 to 50 francs per hectare per year (11*s.* to 17*s.* per acre), but not to the Administration of the canal during at least the first thirty years; so the undertaking requires a great help from the State during this trying period. But in the meantime the State, in the form of taxation, and in the increased welfare of its citizens, reaps a large benefit from these works, which is more than sufficient to repay amply all the sacrifices made for this purpose. Without irrigation Italy would not be able to feed a large portion of its present population; as it is, with its wonderful network of irrigating canals, it has become the 'garden of Europe,' and is now preparing to extend irrigation in order to be able in thirty years' time to feed a population of fifty to sixty million inhabitants. This gives an idea of the satisfactory results accomplished by scientific irrigation, and explains also the reason why the Italian State encourages and helps financially all such undertakings.

(ii.) *Some Factors controlling the Growth of Cotton.*[1]
By H. T. Ferrar, *M.A.*, *F.G.S.*

Among the main factors which control the cultivation of cotton on a commercial basis are :—(1) Temperature, (2) water-supply, (3) soil, (4) labour.

(1) The cotton-plant is commonly found in those parts of the world which lie within thirty degrees of the Equator, but finds its best development in what may be described as sub-tropical climatological regions. In Egypt the air-temperatures which rule at sowing-time are in the neighbourhood of 65° F.; as the plants attain maturity the temperatures gradually rise to values of 82° F. and 83° F. and fall some 9° or 10° during harvest.

(2) The water requirements of the crop are equivalent to about 46 inches of rainfall, which in Egypt is met by irrigation from perennial canals. The water-factor naturally depends upon environment. The methods adopted by the Egyptian cultivators were described.

(3) The volume (depth) of soil available to the roots of the cotton-plant is of more importance than its texture or its chemical composition, provided always that the soil contains sufficient available plant-foods. In Egypt cotton is grown profitably on a soil which in one extreme case is an almost pure sand, and in the other extreme an unctuous clay. Diagrams were exhibited showing how a high water-table, by reducing the volume of available soil, limits the yield of the plant.

(4) The profits derived from the cultivation of cotton naturally depend upon the cost of agriculture. Where the price of labour is high better returns are obtained by cultivating the more valuable types of cotton. The higher-grade Egyptian cottons grow best in the Delta, while warmer Middle Egypt supplies a cotton (*Ashmuni*) whose fibre is of medium value only.

The East Coast of Australia would seem to provide the requisite temperatures and rainfall necessary for cotton-cultivation, but widespread experiment is necessary if it is desired to prove what areas provide suitable soil conditions and what is the margin of profit of the husbandman.

(iii.) *Two Maps illustrating the Fertility of Lower Egypt.*[1]
By H. T. Ferrar, *M.A.*, *F.G.S.*

In an arid country water-supply is the most important factor governing the fertility of the soil, and, given a sufficiency of water, the origin or the chemical composition of the soil is usually of secondary importance. Evaporation being active under arid conditions there is a tendency for salt to accumulate in the soil to the detriment of agriculture. In the United States of America much arable land has deteriorated owing to the accumulation of salts caused by injudicious irrigation, and the next step in Egypt's agricultural progress is the provision of a widespread and efficient network of drains.

The programme of this work is now in hand, and, in order to be in a position to assess the improvement effected after the improved drainage facilities begin to operate, the Egyptian Survey Department was asked to make a survey which would record the present condition of the land. A Fertility Map of part of the Northern Delta was shown. The map on a scale of 1 : 50,000 is reduced from the 1 : 10,000 field-sheets of Mr. F. E. Frith and myself, which are coloured according to an eye-estimate of the value of the land. The agricultural value has been proved to depend upon the salt-content of the soil, and in order to control the arbitrary scale adopted frequent soil-samples have been analysed by Mr. F. Hughes of the Agricultural Department. The mean salt-content of what we have called good land (coloured yellow on the map) is about 0·3 per cent., medium land (burnt sienna) about 0·5 per cent., poor land (sepia) 0·8 per cent., and barren or uncultivated land (purple) 1 per cent. to 20 per cent.

On comparing this map with another on the same scale showing the contours it is noticeable how the fertility depends upon both absolute and relative levels, *i.e.*, upon natural drainage. The good land occurs in the south, and becomes

[1] By permission of the Director-General of the Egyptian Survey Department.

gradually inferior, and finally barren as sea-level is approached, except for narrow strips along the high-lying arterial waterways.

Canals such as these, though sometimes following a tortuous course, are always the most satisfactory, firstly because they easily command the country they serve with irrigation water, and, secondly, because the evils of salt-accumulation consequent on active infiltration are reduced to the lowest possible minimum. Conversely, drainage channels are not fully efficient unless they follow closely the lowest parts of depressions between opposing elevations. In Egypt differences of level are usually comparatively small; nevertheless, remodelling of water-channels, which in the old days were not excavated according to the contours, has formed part of the irrigation programme since the British occupation of that country.

It is understood that some Australian irrigation projects have not been entirely successful owing to difficulties such as are indicated, and it is urged that it is an economy to spend money on detailed mapping of new country before launching on projects of canalisation, which if lacking in finality may entail a greater outlay on remodelling than would have been needed for the initial survey.

'When we mean to build,
We first survey the plot, then draw the model.'

(iv.) *Irrigation in Victoria.* By J. H. Dethridge.

Sydney.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *Migration of Reserve Material to the Seed in Barley considered as a Factor of Productivity.* By E. S. Beaven.

With barley the ratio of the dry matter accumulated in the seed to the total dry matter of the plant when fully ripe frequently influences the produce of grain to a greater extent than any other factor; also it is more important in barley than in either wheat or oats, because the value of the dry matter of the haulm (*i.e.*, the stem and leaves) is less with barley; also this ratio is higher in some races of barley than in any variety of the other cereals, and probably higher than in any other cultivated plant. The paper dealt with some of the bearings of these facts.

This ratio varies considerably as between different varieties of barley and as between different races of the same variety of any cereal species. It has a high value for purposes of selection, especially in the early stages of selection from amongst a limited number of individual plants which are the progeny obtained by the artificial cross-fertilisation of any two individuals.

As between two races, each the progeny of a single plant of the F4 generation of the same cross, and with the same weight of dry matter in the entire plants on unit area, the inherited and persistent difference in the ratio referred to has been found in a series of experiments to be as much as 5 per cent. In consequence of this factor alone with the same total weight of grain and straw on unit area the yield of grain was more than 10 per cent. greater in some such races than in others.

In the case of hybrid races generally the number of individuals possessing different combinations of characters is very large, especially if minor characters affecting either productivity or quality are taken into account. The experimental error involved in selecting either individual plants, or aggregates which are the progeny of single self-fertilised plants, for the purpose of starting new races of cereals is so great in consequence of environmental conditions that no conclusions of practical value can be drawn, except from a very large number of observations, as to relative productivity when only the dry weight of the grain is taken into account, and then only if special methods of cultivation are adopted.

In the initiatory stages of new races it becomes, therefore, impracticable with any certainty to extract the most productive races from those originated by artificial crossing by the merely empirical methods hitherto adopted.

The paper described the methods adopted in collaboration with Professor Biffen, and, in respect of the biometrical data obtained, with Mr. W. E. Gosset, and gave a summary of the conclusions arrived at from the experiments of the last five years; more particularly as to the value for selection purposes of accurate determination of the relative seed-forming energy as shown by the 'coefficient of migration' of different races of barley.

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2. *Wheat Improvement in Australia. By* F. B. Guthrie, *F.I.C.*

Part I.

Early inter-State action with regard to the study of wheat and its diseases was reviewed, and it was shown how the original scheme developed.

The work of private individuals, working before State action was inaugurated, was discussed, and in particular the present position of the Farrer wheats was dealt with.

The special qualities looked for in wheats to be grown under Australian conditions were grouped under the following heads:—

(1) Resistance to rust and other diseases.
(2) Prolificness.
(3) Drought resistance.
(4) Milling quality.
(5) Wheats for hay.
(6) Wheats for different districts and climates.

It was shown how the interpretation placed on the above terms in Australia differs from that which obtains in other countries on account of the differing conditions; for example, wheats which resist rust locally succumb to this disease when grown in other parts of the world; some of the most prolific European varieties are very poor yielders when grown locally, &c.

The characteristics enumerated above were next considered more in detail.

(1) *Resistance to Rust, &c.*—The principal workers on this subject were referred to. The point was noted that the nature and life-history of rust were different in Australia. The question of rust-escaping by quick maturing was dealt with, and the damage done by rust in Australia, especially in the coastal districts, was discussed.

Remarks followed on some rust-resistant wheats.

(2) *Prolificness.*—The importance of this quality from a farmer's point of view. In the older wheats prolificness was very frequently associated with inferiority in other respects. The smallness of local yields was considered in comparison with other countries. The characteristics required in a prolific wheat were reviewed and some successful new varieties described.

(3) *Drought Resistance.*—It was shown that this property is of the greatest local importance in view of the extension of wheat-growing into drier areas. The characteristics to be looked for in dry country wheats were discussed, and some successful new varieties described.

(4) *Milling Qualities.*—The different requirements of English and Australian millers were referred to, and the characteristics of a good milling wheat for Australian conditions discussed. The export and internal trade were reviewed, and it was shown that there is a steady improvement in the quality of our locally grown wheat. Notes followed on some of our best-milling wheats.

Part II.

The work done in the individual States in the improvement of wheat was reviewed under the following headings:—

(1) Work done by individual investigators.
(2) Work carried out at institutions under departmental control.
(3) Action taken by the different States in furtherance of the object of improving wheats.

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3. *William Farrer's Work, Methods, and Success: a Short Sketch.* *By* J. T. Pridham.

Farrer, the famous wheat-breeder, was born in England in 1845 and had a distinguished career at Cambridge. He emigrated to Australia for health reasons, and after practising as a surveyor he started his wheat-breeding experiments on his own property at Lambrigg, New South Wales, in 1886. In 1898 he became wheat-breeder to the State Department of Agriculture and was actively engaged in this great work till the day of his death in 1906.

What first attracted his attention to wheat improvement was the damage done for a number of years by rust (*Puccinia graminis*), and he set himself the problem of producing a rust-resisting variety. Other features which he aimed at securing were greater flour-strength, drought-resistance, early maturity, freedom from shelling, suitability for hay-making, and immunity to bunt (*Tilletia tritici*). Prolificness he regarded as of secondary importance, although this is the leading characteristic of his most popular variety, 'Federation.' He seems to have thought that proper attention to cultivation, manuring, &c., were of more importance in securing high yields than the actual prolificness of a particular variety.

Cross-breeding followed by selection from the varying progeny formed the basis of all Farrer's work, and he usually made between 200 and 400 crosses in each year after joining the Department. The varieties used in addition to the best local ones were chiefly of the Fife type from Canada and the United States to impart strength, and Indian varieties to give early maturity and capacity for holding the grain after ripening. The selection of the best cross-breds and the elimination of the unsuitable ones presented the greatest difficulties he had to encounter. He was greatly helped in this by the setting-up of a miniature flour-mill under the superintendence of Mr. F. B. Guthrie, the departmental chemist; for this made it possible to determine accurately the milling and baking qualities of very small samples of grain, any varieties not coming up to a certain standard being immediately rejected. He kept well abreast of the current literature on the subject, and although during his later years he was in correspondence with Professors Biffen and Spillman on the subject of Mendelism he did not see his way to alter his methods materially, except, perhaps, in reducing the number of crosses made.

His work proved successful beyond his wildest dreams, though it was only partially appreciated at the time of his death. His greatest popular success is 'Federation'—a variety first introduced to the farming public about 1901 and now the most extensively grown and prolific of any in Australia. It is a cross between 'Purple Straw,' one of the best all-round local varieties up till Farrer's time, and a Fife-Indian cross-bred called 'Yondilla.' In addition, he has produced varieties ('Comeback,' 'Bobs,' and 'Cedar') of much greater flour-strength than any previously grown; varieties relatively immune to rust ('Warren' and 'Thew'), suitable to the moister districts near the coast; varieties not subject to bunt ('Florence,' 'Genoa,' and 'Cedar'), early-maturing varieties —some of them suitable for hay-making, like 'Firbank' and 'Bunyip,' and most of them hold their grain better and are more suitable to Australian harvesting methods than the majority of the older varieties. Since his varieties have come into general use the growth of wheat has extended into drier and drier districts and a new province has been added to the 'wheat-belt' in New South Wales, while the average milling and baking qualities of Australian wheat have improved year by year.

In the opinion of the author the main factors which contributed to Farrer's success were his keen enthusiasm, perseverance, thoroughness, and singleness of aim, coupled with the assistance of the Government, which caused the new varieties to be thoroughly tested and finally introduced to the farmers.

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4. (a) *Variety Testing and* (b) *Strength of Wheat Flour.* *By* Professor T. B. Wood, *M.A.*

5. *Wheat-Breeding in Australia.* *By* A. E. V. Richardson, *M.A., B.Sc.*

Wheat is the staple crop of Australia. Steady increase in production has taken place during the past three decades, and the annual production is now approximately 100 million bushels. The greatest increase has taken place during the past decade, the area of land under wheat for grain rising from $5\frac{1}{2}$ million to $7\frac{1}{2}$ million acres, and the production from 50 million to 100 million bushels. The factors mainly responsible for this increase are the opening up of lands hitherto regarded as unsuitable for wheat-culture, the adoption of labour-saving machinery and improved methods of culture, and the introduction of improved varieties of wheat.

Hitherto, attention has been mainly directed to the improvement in the plant's environment, as contrasted with the improvement in the plant itself.

The future magnitude of the wheat industry of Australia depends on the extent to which lands lying outside the existing margin of cultivation can be profitably farmed. These are the semi-arid areas, and, to make them fully productive, drought-resistant prolific types are urgently required.

In the three principal wheat States, New South Wales, Victoria, and South Australia, wheat-breeding is an important activity of the local Department of Agriculture. Each State has a central station at which wheat-breeding is conducted, and subsidiary farms at which new selected cross-bred varieties are tested. At these centres considerable progress has been made in the production of more prolific types by—

(1) The isolation of pure strains and mutants of high yielding capacity from the locally grown types;

(2) The deliberate improvement of existing types by individual and mass selection;

(3) The introduction and acclimatisation of foreign wheats;

(4) The improvement of selected local types by intercrossing and by crossing them with acclimatised foreign types.

A summary of this work was submitted.

Farrer has conclusively demonstrated by cross-breeding that the production of varieties of high prolificacy, of high milling and baking quality, and of a high immunity from disease, is a practical certainty. The varieties 'Federation,' 'Bobs,' 'Cedar,' and 'Comeback,' 'Florence' and 'Genoa,' may be taken as illustrations in point.

There is reason for believing that the drought-resisting qualities of proved Australian varieties could be greatly increased by using as foundation stocks wheats grown for generations under extremely arid conditions. Certain crosses of Durum and Indian wheats with prolific local types have resulted in the production of early-maturing, spare-stooling, drought-resistant types bearing a high proportion of grain to straw.

Modern genetic research has thrown considerable light on the mode of inheritance of certain unit characters in wheat, but most of the characters hitherto studied are of little practical importance. The practical objectives from an Australian standpoint are the raising of prolific, drought-resistant, early-maturing types, immune from fungoid diseases. To these may be added strength of flour and high milling quality. We require to determine what are the various factors on which these important qualities depend, their mode of inheritance, and how they can be brought under control and associated together at the breeder's will.

TUESDAY, AUGUST 25.

Joint Discussion with Section B (Chemistry) on Metabolism, opened by Professor H. E. Armstrong, *F.R.S.*

Professor Armstrong: In the time at disposal only broad issues could be considered. Many attempts had been made of late years to prove that formaldehyde is the initial product of assimilation. Apart from the unsatis-

factory character of the evidence adduced, proof that it is present in the living plant can never be proof that it has been formed in the up-grade process of assimilation, as there is reason to believe that it is a constant product of down-grade metabolism. However formed, its properties are such that it can never be present in more than minimal quantities; moreover, the fact that proof cannot be given that it is formed initially is of little consequence, as it is scarcely required, there being no other way apparently of accounting for the assimilation of carbon dioxide except the assumption that it is initially reduced to formic acid and then to formaldehyde. As to the manner in which carbonic acid undergoes reduction in plants, it is probable that water is 'electrolysed' under the influence of light and chlorophyll, the one product being oxygen, which is evolved, perhaps, under the influence of a catalase, the other hydrogen, which is gripped temporarily by the chlorophyll and then used in reducing the carbonic acid. To assign a secondary part to chlorophyll and to regard iron salts as the primary agents, as Moore has done, is to overlook all that is known of the former substance and of the function of iron salts.

To account for the formation of optically active dextroglucose in the plant, to take only one example, it is necessary to suppose that the polymerisation of formaldehyde is a directed process: probably it is formed against a sugar template, maybe under the influence of an enzyme. The enzymes, in fact, are to be regarded not only as hydrolysts but also as the primary formative agents of all directed metabolism. The manner in which they act reversibly may be well illustrated by reference to the behaviour of lipase. (Curves were exhibited showing the manner in which the synthetic and hydrolytic activities of lipase come to an equilibrium in presence of various amounts of water; it is most effective as a synthetic agent in the absence of water, a small proportion of water having a great effect in reducing the synthetic activity of the enzyme.[1])

The enzymes are rigidly selective agents. They appear all to be colloid materials, and therefore cannot be regarded from the same point of view as ordinary hydrolytic agents such as the acids; much confusion has been caused by the introduction of complex mathematical considerations in explanation of their action. Apparently they act at approximately linear rates, but as one or more of the products of change exert a retarding influence, the apparent rate of change is more nearly of a logarithmic order.

Though starch is the first obvious product of assimilation, there is no reason to suppose that it is a necessary stage in the formation of the other carbohydrates met with in plants, as in monocotyledons and not a few other plants it only occurs in the guard cells and then only in minute amounts. Brown and Morris have, in fact, argued that cane sugar is the primary product of carbohydrate metabolism. A very thorough study of the problem is now being made at Rothamsted by Mr. Davis and others which promises to be of importance, especially as particular care is being taken to devise accurate methods of analysis. In no case has starch been found in mangold leaves except at a very early period, though cane sugar is always present together with invert sugar; apparently cane sugar wanders directly from the leaf into the bulb; maltose has never been detected, though specially looked for, so that it is probable that cane sugar is formed directly, not from maltose.

Reference was made to the great importance to the agriculturist of exact methods of analysis and of knowledge based thereon of the composition of fodder crops: it was to be supposed that much could be done to improve the quality of the various crops if once the general character of their metabolism were established. Improvements in the methods recently effected at Rothamsted were then briefly described—particularly the method which Mr. Davis had introduced of estimating starch with the aid of Taka-diastase, whereby a mixture of maltose with glucose is produced instead of a mixture of maltose with dextrins of uncertain properties. To determine maltose with accuracy, Mr. Davis uses yeasts which were known to act selectively on this sugar (*Saccharomyces exiguus*, *S. Ludwigii*, &c.). Incidentally, in the course of this work, the important fact has been established that yeasts which do not hydrolyse maltose also cannot assimilate; the contrary results of previous workers

[1] Cf. Armstrong and Gosney, *Proc. Roy Soc.* Series B, 1914.

are to be explained by the presence of a protein impurity in the maltose used. With the aid of such yeasts it has been possible to show that even in plants such as the Potato, the Turnip, and the Nasturtium, which contain much starch in their leaves, maltose is never formed as a down-grade product of metabolism.

Professor Armstrong took exception to Dr. Petrie's conclusion that certain plants contained hydrogen cyanide in the free state: he regarded its presence as an impossibility and thought that probably in such cases the glucoside and enzyme were not separated so effectively as they are in most plants, so that they came together very readily on the cessation of metabolism.

(i.) *Feeding Statistics and Starch Equivalents.* *By* Professor T. B. Wood, *M.A.*, *and* G. Udny Yule, *M.A.*

The authors have made a statistical study of the results of about 400 feeding trials collected and tabulated for the Highland and Agricultural Society by H. Ingle.[1] The trials were all carried out with oxen or sheep in Great Britain before the year 1907. Some of them go back to the year 1839. Examination of the results has yielded the following conclusions :—

1. When the diet of oxen or sheep is increased above maintenance requirements the law of diminishing return asserts itself, and successive increases in the diet do not produce proportional increases in live weight.
2. As the diet is increased above maintenance requirements a smaller proportion of each successive increase is converted into live weight, and consequently a larger proportion is lost as heat.
3. When oxen or sheep in store condition are given a diet which supplies considerably more food than is required for maintenance the proportion of the excess of food above maintenance requirements which is converted into live weight continuously falls as fattening proceeds.
4. From the above conclusions it follows that there is not a direct proportionality between the amount of food above maintenance requirements calculated as starch equivalent and the live-weight increase produced.
5. The figures from which Kellner's starch equivalents were calculated show a direct proportionality between the amount of starch equivalent above maintenance requirements and the live-weight increase produced.
6. The discrepancy is explained by the fact that Kellner's results were obtained by feeding animals in store condition for short periods during which they never approached what the butcher calls ripeness, whilst in the British trials the animals were fed for several months until they were ripe for the butcher.
7. It is by no means rare to find individual oxen which on an average fattening ration of 8·5 lb. of starch equivalent above maintenance requirements make daily live-weight increases as large as 3 lb. or as small as 1 lb. The former should give out 17,000 cal. per day, the latter 22,000 cal. per day, a difference of about 25 per cent. It should be possible to detect differences of this order by measurements of skin temperature.

(ii.) *Fattening Capacity and Skin Temperature.* *By* Professor T. B. Wood, *M.A.*, *and* A. V. Hill, *M.A.*

The authors have measured the skin temperatures of eighteen oxen which had been on a fattening diet for ten weeks at the Norfolk Agricultural Station. The measurements were made by means of a thermopile connected to a sensitive galvanometer. The following results were obtained: The average skin temperature of eight animals which had during the last three weeks made average daily increases in live weight of 2·7 per head was 69 scale divisions above air temperature. The average skin temperature of five animals which had during the same period increased less than ·8 lb. per head per day was 78 scale divisions above air temperature. The good doers had cooler skins than the bad doers by nine scale divisions, which corresponds to approximately 3° C.

[1] *Jour. High. and Agr. Soc.*, 1909, 1910.

Further discussion :—

Prof. W. A. Osborne: Investigation of skin temperatures has a quite different significance when the shade temperature of the air is equal to the normal temperature of the animal. In this case, even in the driest-skinned animals the skin temperature is generally below that of the air. When the shade temperature of the air is higher than that of the animal the skin temperature may be higher than that of the internal organs.

Thickness and texture of coat and thickness of skin are factors of some importance.

Prof. B. Moore: In the photosynthetic processes by which aldehyde is first formed the association of colloidal iron salts with the colourless organic portion of the chloroplast plays a distinct part. The metabolic conversions occurring in plants and animals from one type of carbohydrate to another are not difficult to account for by simple enzyme action because the energy charges are so slight, but the synthesis in the metabolic processes of protein and fat from carbohydrates requires a linkage and co-ordination of an endothermic with an exothermic reaction, such as has never been observed with a simple enzyme. For such synthesis an adsorption of enzymes into the cell protoplasm is required so as to furnish a colloidal regulating mechanism able to alter its activities from one time to another, and to build up or break down according to the demands of metabolism.

In certain invertebrates and fishes there is an excessively low rate of metabolism, and a relatively enormous portion of food energy is thrown into the metabolism of the sex organs in such animals, as compared with the somatic metabolism.

Mr. G. P. Darnell-Smith: The first visible product of assimilation in plants is starch, and the absence of visible starch in a plant does not show that it is incapable of forming it, but that its metabolic processes and its rate of translocation are so rapid that there is no need for starch to be deposited. For starch is to be regarded, not as a first product of assimilation, but as a substance that is thrown down temporarily by rapidly assimilating plants until such time as the plant is able to deal with its translocation. Brown and Morris regarded cane sugar as the first product of assimilation, but a critical examination of their experimental results fails to carry conviction.

As regards enzyme action confusion is introduced by comparing it with, for example, the rate of hydrolysis produced by acid. It has to be remembered that an enzyme is a colloid, and that the action of a colloid is determined by its previous history. Unless the previous history of a colloid is known, its action cannot be predicted; hence a portion of any particular colloid under particular conditions will act in a different manner from another portion of the same colloid (but with a different previous history) under the same particular conditions.

Mr. D. McAlpine: The question whether chlorophyll has any action in the green plant in the absence of sunlight is uncertain. Its photosynthetic activity is probably slight, yet it is found where sunlight could not possibly penetrate, as, for example, in the so-called fruit of the yew, the seeds of the lemon, and in the conducting parenchyma throughout the tissue of the apple.

(iii.) *The Distribution of Nitrogen in the Seeds of* Acacia Pycnantha. *By* Dr. J. M. Petrie *and* Dr. H. G. Chapman.

The seeds of a pycnantha which have been dried in the air contain 4·5 per cent. of nitrogen. If the testa be removed the seed contains 5·5 per cent. of nitrogen. The nitrogen is present partly as protein and partly as various organic compounds.

The nitrogen present as protein forms 55 per cent. of the total nitrogen. The protein soluble in water contains 26 per cent. of the total nitrogen; that soluble in 10 per cent. NaCl 13 per cent. of the total nitrogen, and the remainder could not be extracted. Protein soluble in alcohol is absent. Protein coagulable by heat contains 10 per cent. of the total nitrogen.

The nitrogen present after precipitation with 80 per cent. alcohol amounts to 45 per cent. of the total nitrogen.

Of the non-protein nitrogen, 10 per cent. is driven off by distillation with magnesia and 18 per cent. is precipitated by phosphotungstic acid.

After hydrolysis of the solution of non-protein nitrogen with dilute acid for two hours, the amount of nitrogen distilled over with magnesia is 10 per cent. of the non-protein nitrogen, but if now the hydrolysis be repeated another 10 per cent. of the non-protein nitrogen distils over. If hydrolysis be long continued, the amount of nitrogen that can be distilled over with magnesia rises to over 30 per cent. of the non-protein nitrogen.

If the non-protein solution be hydrolysed for two hours with dilute acid, then nitrous acid liberates nitrogen corresponding to 66 per cent. non-protein nitrogen. If, however, the hydrolysis be repeated long enough the liberation of nitrogen by nitrous acid diminishes to zero.

With Sorensen's method of titration no fixation of formaldehyde by amino-groups occurs.

The attempts to isolate amino- acids invariably resulted in the discovery of traces.

The amount of purin nitrogen present is small, less than one per cent.

The following Papers were then read :

1. *Bacterial Toxins in Soils.* *By* R. Greig-Smith, *D.Sc.*

If the soil-water is considered as a medium for the growth of bacteria, it should contain not only the nutrients that favour bacterial growth but also the waste products of their vital activity. And if we reason from what we know about the growth of bacteria in other media, we should expect that some of these waste products are injurious to the bacteria producing them. Furthermore, in a mixed flora, certain groups should produce injurious substances in greater amount, and these should differ in degree in their action upon bacteria of their own group or of other groups. For convenience, these injurious substances are called toxins. Certain investigators deny the presence of toxins in soils, although they admit the presence of inhibiting substances. It is difficult to account for the discrimination.

The multiplication of bacteria in the soil will among other conditions depend upon the relative preponderance of the nutrients over the toxins; and, with the other conditions remaining constant, an ultimate equilibrium should be established between the nutritive and the toxic effects. An alteration of the other conditions will disturb the equilibrium, and the bacteria will increase or decrease until another balance is established.

In demonstrating the presence of bacterial toxins in soils, I have made use of aqueous extracts of soils which after filtering through porous porcelain have been seeded with known quantities of bacteria. Generally, *Bac. prodigiosus* has been employed as a test organism. It is more sensitive than mixtures of soil bacteria, and is easily grown, detected, and counted. Tests have shown that extracts which destroy *Bac. prodigiosus* retard the growth of mixed soil-bacteria. We are justified in considering that an extract which destroys *Bac. prodigiosus* is also capable of destroying some of the soil-bacteria.

The bacterial toxins are not always easily demonstrated, as they are frequently overshadowed by the soil-nutrients, but investigation has pointed out some of the conditions under which they may not be expected to show a direct action in soil-extracts. For example, they are destroyed by exposing the soil to the sun, by heating the soil, by storing the soil in the air-dry condition; they decay rapidly in aqueous solution, and are destroyed upon boiling. They are soluble in water and are washed out of the soil by rain. Direct evidence of their presence should not, therefore, be expected in arid soils, in soils during a drought or in soils after rain. Much of the so-called fertilising effect of the sun may be due to the destruction of the soil-toxins. Indirect evidence of their presence is easily obtained by boiling the soil-extract, seeding it with bacteria, and comparing the growth with that obtained in the unboiled extract. A greatly increased growth of bacteria is usually obtained in the boiled extract. A direct diminution is only obtained under certain conditions. These have not been fully investigated, but enough has been done to show that one of

these depends upon the ratio of the soil to the water used for extraction. Equal parts of soil and water—that is, 100 grams of soil and 100 c.c. of water—generally give the maximum toxic effect.

The toxic effect is not evident after rain, but becomes pronounced after a few days of dry weather. Similarly, a soil which has been extracted with water, and found to be toxic, will, upon further extraction, give a nutritive extract. If the same soil, after extraction, be incubated at 22° for some time and then extracted with water, the extract will be found to be toxic. Thus toxins are developed upon incubating a nutritive soil.

While the extracts of soils show an enhanced nutritive effect after boiling, those of the subsoil become more toxic. It appears, therefore, that there are at least two kinds of toxins in soils—one, predominating in the soil, is thermolabile; the other, predominating in the subsoil, is thermostable.

The action of the volatile antiseptics upon soils is to so alter them that, while before treatment they yielded extracts directly bacteriotoxic, after treatment the extracts became nutritive. Thus the partial sterilisation of soils, whether by heat or by volatile antiseptics, causes them to give extracts, in which there can develop a greater number of bacteria.

2. *A Review of Work on Soil Inoculation.* *By* J. Golding *and* H. B. Hutchinson.

Since the introduction of pure cultures of nodule bacteria for soil inoculation by Nobbe and Hiltner in 1895 a vast number of field experiments has been carried out in different countries and with a great variety of inoculating material.

The results of such experimental work were in the first instance most discouraging, and it is only within the last few years that the conditions determining success or failure have been adequately recognised. During this time the relations existing between the host plant and the nodule organism and between the organism and artificial media used for cultivation in the laboratory have been studied in detail, and in the light of these investigations it is not surprising that failure attended much of the preliminary and often haphazard field work. Experience has shown that it is not sufficient to have a pure and active culture in order to attain success in soil inoculation, but that the soil itself shall be suitable for the growth and continued existence of the introduced organism, and that the supply of mineral nutrients shall not be the limiting factor in the growth of the plant. Liming has been required in many cases, and with a proper recognition of the now known essential conditions the number of successful cases of inoculation trials has steadily increased during recent years.

Comparative work with pure cultures and inoculation by means of soil which has previously carried a specified leguminous crop have shown in the majority of cases the superiority of the latter, and cultivation in the laboratory has latterly included the use of soil media or soil itself, since the organism appears to retain its power of infection to a greater extent in this than in other media.

The use of pure cultures possesses advantages on the score of cheapness and convenience, which are sometimes of distinct value, and recent work especially has shown the danger attending transference of plant diseases in soil used for legume inoculation. The relations attending infection of the plant and subsequent mutual existence are very complex, and future experimental work in preparing cultures must aim at reproducing these conditions in order to permit of the production of cultures in active growth and possessing great virulence.

Such work, however, involves accurate scientific control if it is to be of permanent benefit to science and agriculture, and in itself would tend to check the production of commercial cultures of doubtful origin and hypothetical value.

3. *The Effects of Caustic Lime and of Chalk on Soil Fertility.* *By* H. B. Hutchinson *and* K. MacLennan.

Bacteriological, chemical, and pot-culture investigations with the two forms of lime have shown their action on the soil to be essentially different. The

former possesses the essential properties of a mild antiseptic, and if applied in sufficient quantity is capable of giving rise to the usual phenomena of partial sterilisation. When this point has been reached there occurs an initial decrease in the numbers of bacteria, followed by large increases, the larger forms of soil protozoa are killed, and there is a cessation or limitation of nitrate formation. The form of available nitrogen in such soils is largely that of ammonia, which leads to increased nitrogen content of plants growing in such soils.

Both above and below the partial sterilisation point the return of nitrogen as ammonia and nitrate within the first year is directly proportional to the amount of caustic lime applied, and if not assimilated by the crop is liable to loss by leaching before the following crop appears. This is advanced as an explanation of the unfavourable results sometimes observed in practice after heavy applications of caustic lime. Lime in this form and about the partial sterilisation limit may be used for the suppression of insect pests in the soil. In common with chalk or limestone it also serves to correct an unfavourable reaction of the soil, thus ensuring more vigorous bacterial and plant growth.

Three new methods have been worked out to ensure better control of the use of lime in field practice: (*a*) the determination of soil carbonates; (*b*) the determination of the amount of caustic lime necessary to induce partial sterilisation, and to indicate the limit to which this form of lime can be applied without adversely affecting the following crop; and (*c*) the estimation of the lime requirements of soils for purposes of neutralisation, whether by means of caustic lime or carbonate.

While the estimation of soil carbonates may provide useful information in some cases, the authors wish to lay especial emphasis on the desirability of determining the lime requirements of the soil, since a soil may contain only traces of carbonate and still not be in need of lime applications.

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4. *The Estimation of Condition in Cattle.* *By* J. A. MURRAY.

In this paper it was argued:

(1) That the verbal terms—fat, half fat, &c.—used to describe the condition of cattle are vague and indefinite.

(2) That all the varying degrees of condition can be expressed only by numerical values.

(3) That condition is measured by the ratio of live weight to size.

(4) That the size may be determined by the usual measurements of length and girth.

(5) That the girth must be that of the animal in store condition. Under any other circumstances some allowance must be made for the increase in girth due to fattening.

(6) That the condition of typical store animals should be taken as 100, and that of others *pro rata.*

The arguments are embodied in the formula:—

$$C = \frac{424{\cdot}4\ M}{l\left\{g - \frac{g}{200}(M/l - 17)\right\}}$$

where C is the condition, M the live weight (in pounds), and g the length and girth respectively (in inches).

This formula is at present tentative, and is merely intended to show that the thesis is capable of practical application. The chief difficulty in the way of developing it is the unreliability of the accepted methods of measuring length.

The paper was therefore mainly a plea for co-operation of cattle experts with a view to (1) agreement in regard to the methods of measurement, (2) accumulation of data relating to different types of animals.

Brisbane.

FRIDAY, AUGUST 28.

The President delivered the following Address :—

The fact that this Address is to be delivered in the capital city of a State in which semi-tropical, and even tropical, conditions prevail suggests some consideration of the future of countries in which vegetative development, and therefore the production of food, can attain such a level as is possible here.

At the outset let me remind you of two prime facts in the natural history of man. In the first place all civilisation is based upon food supply; no other industry is creative, and the wealth of a community might almost be measured by the amount of time that remains at its disposal after it has secured, either from its own land, or by exchange, the food it needs to live upon. Secondly, we must look forward at no very distant date, as the life of nations goes, to the exhaustion of those capital stores of energy in the world—coal and oil—on which the current industrial system is based. How long the stores may last is a matter of dispute, but 500 years is a liberal estimate, and we can be pretty sure, in a world in which prophecy is notoriously unsafe, that nothing remains to be discovered which can take the place of those savings from the energy of bygone epochs that are represented by coal and oil. With the passing of industrialism the importance of agriculture will grow, and while the world as a whole will still be able to support the same number of people as are fed by agriculturists of to-day, great readjustments of the population will have to be effected, according to the productive powers of the land in each country. Should population continue to increase, and the spread of organised and stable government ensures that it will grow, there must come a demand for the better utilisation of the land, and for a higher production of food than at present prevails; indeed, even in the last few years symptoms of this increasing demand for food have been in evidence.

Let us see what the land can be made to do at the present time in the way of supporting population, and for that we must turn to the East, where long experience of the art of intensive agriculture goes hand in hand with an optimum climate and a population of maximum density. Rural Japan is reported to carry a population of 1,922 to the square mile, entirely supported by agriculture, but maintaining in addition its quota of officials and industrialists. Even this number is exceeded in China, where a farm of two-and-a-half acres will support a family of eight to ten people, and where, in some special cases, as on the island of Chungming, the population living wholly on the land may rise nearly to 4,000 per square mile. Compared with these figures the density of population on Western land is trifling. The United States is said to maintain no more than 61 per square mile of its cultivated land, England something over 90, Ireland about 120, and Belgium, perhaps the most intensely cultivated of European countries, not more than 200 per square mile of cultivation. Now, these enormous densities of rural population are accompanied by a very low standard of living; the people, if strong and healthy, exist on the very margin of sustenance. To take a cash standard, an experienced rural labourer in China cannot command more than 6*d*. a day, on which he will support a family. But for this small pay of 6*d*. a full day's work will be obtained; indeed, such a day's work as the white man would find it almost impossible to give under the climatic conditions prevailing.

Such a state of continuous toil seems to be the necessary outcome of an individualistic system of farming in countries with no great industrial outlets, where the pressure of an increasing population results in continued subdivision of the land. Of its kind Chinese agriculture is magnificent, as far as one can judge from the accounts; the land is made to do an extraordinary duty, bearing two or three full crops a year; waste is non-existent, and long experience has taught the farmers to anticipate in practice some of the most recent discoveries of science in the way of conserving and recuperating the fertility of the soil. Though no statistics are available, the land seems to have been raised to its

highest level of productivity per acre, just as it has attained its maximum population-carrying capacity.

Now the Australian, like other farmers in new countries, is often reproached for the low yields per acre that he obtains—10 to 15 bushels of wheat per acre, as against 32 in England, and rather more in Holland and Belgium. Unfavourable as is this comparison of Australia with Europe, still greater appears the superiority of China and Japan, though it cannot be reduced to statistics. But the Australian quite rightly replies by setting up another standard of comparison; not the production per acre, but the production per man is his criterion, and on this basis the Australian farmer takes a very high position indeed. Against the productivity of the land when labour is unlimited he opposes the ideal of the productivity of the man when aided by machines and unlimited land.

Organised large-scale farming supports far more people than the labourers actually employed on the land; it buys machines and raw materials like fertilisers, it pays rent and makes profits, all of which go to the support of other people, who are at bottom fed and maintained by the production from the land. I have calculated that the most highly cultivated farm with which I am acquainted in Britain, a farm selling merely meat, potatoes, and corn, would actually support people at the rate of over 1,000 per square mile, if they were to live at such a low subsistence level as that of the Oriental small farmers. The standard of living that in fact prevails is of course very different, but nevertheless, when all the exchanges of commodities and services against food are completed, that square mile of highly organised farm-land is the ultimate support of a population comparable with that resident on Eastern land even though the number of people actually tilling the soil is small enough.

But even if the number of people maintained by a given area under Western conditions is far greater than would appear from those employed in cultivating the soil, there must come a time when the pressure of an increasing population will necessitate a much higher agricultural efficiency in the way of production of food per acre. Now, if we attempt to meet this pressure by subdivision of the land, attracted by the specious appearance of a large population supported on the soil, the operation of competition will force them down to such a low standard of living as we find in China and Japan. A large number of men on the land does not necessarily make for more food for the community, because in practice we find that the standard of cultivation and production per acre of the small holder is actually below that of the larger farmer in the same class of business. For example, one thousand acres might be cultivated by twenty men, so as to produce as much food as if it were divided up and made to carry 200 men on five acres apiece; the community, considered as a whole, is richer in the former case by the labour of 180 men, labour that can be devoted to the production of other articles which the small holders would have to go without. Clearly, if twenty men can grow a maximum of food on the thousand acres, it is mere waste to employ 200 men about it, though, at first blush, in the latter case, the land seems to be carrying ten times more men. The only question is whether the intensive cultivation, which is more or less forced upon the two hundred holders of five acres, can be obtained when the area is cultivated, as a whole, by only twenty men. There is no lack of evidence that it can, but the means by which such large-scale farming can in the end beat mere grinding human labour, is by utilising to the full all the resources of science, machinery, and organisation. In fact, when the world becomes fully populated, the application of science to agriculture is the only method by which the community can be saved from falling into the Oriental condition of a community of labourers working incessantly for a bare subsistence.

Now, we may ask ourselves what remains for science to do towards the improvement of agriculture. Practically everything. Agriculture is half as old as man; centuries of experience, of trial and error, of slowly accumulated observations, are bound up in the routine of the commonest cultivation of the soil; the science applied to agriculture is at the outside little more than a century old, and so far has only partially succeeded in explaining and justifying existing practices. It is still in the reign of first approximations to the truth; these specious first approximations which so regularly break down when applied to

the real thing on a large scale, where the second or even the third terms really dominate the issue. The farmer is fond of reproaching the scientific men with the discrepancy between theory and practice; there should be none if the theory is complete, but in such complex matters as the growth of plant and animal we are yet very far from being able to bring into account all the factors concerned. A shipbuilder, for instance, having built to a certain speed and measured off his distance on the map, may reckon on making his port on a certain day; he finds himself wrong, because of the existence of a current which takes a knot or more off his speed. His theory was not wrong, only incomplete. Fuller knowledge may map the currents and their velocity, but even the new calculation may be put out by some unexpected weather factor. Now the growth of a plant is determined by an infinitely more numerous and less measurable series of factors than the speed of a ship : small wonder then that the calculations based upon them are apt to be so erroneous.

Imperfect as is our knowledge, yet we have progressed far enough to see in what directions fruitful work may be done, and may plan our campaign of research. In connection with the soil, for example, the big problem is probably the prevention of the waste that goes on at an increasing rate as the soil becomes more enriched by the accumulation of organic matter. Many soil bacteria, as we know, deal with the compounds of nitrogen in the soil so as to set free nitrogen gas from them, all of which actions are sheer waste of the most valuable constituent of the soil, and to such an extent does this change take place that we cannot, as a rule, expect to recover in the crop more than one-half of the nitrogen contained in farmyard manure applied to the soil. Where the soil is rich, and a high level of production is being arrived at, the percentage of waste may be even greater; for example, on the Rothamsted wheat plot, which has received 14 tons of dung every year, only about one-quarter of the nitrogen applied in the manure has been recovered in the crop, and less than a quarter remains stored in the soil. When a hundred pounds of nitrate of soda per acre is applied, nearly the whole of the nitrogen it contains will be recovered in the increased crop; with an application of 200 lbs. there may be a waste of 25 per cent. of the nitrogen, with still greater losses as the application is increased. The loss is not due to mere washing out of soluble materials, because it is greatest when the nitrogen is applied in organic manures. Under existing conditions, high productivity in the soil is associated with a high rate of waste, and nowhere is this more marked than when cultivation is carried on under tropical conditions, so that one of the chief difficulties of tropical and semi-tropical agriculture is to maintain the stock of humus and nitrogen in the soil. An illustration of the waste that so often goes on in the soil is furnished in the practice of the cultivators under glass in England. For the growth of cucumbers and tomatoes they are in the habit of making up a very rich medium, half soil and half dung, but after a very few crops they are no longer able to use this mixture profitably, but must throw it away and renew their beds, though the rejected soil is still extremely rich in the elements of plant food. The recent investigations at Rothamsted have shown that the fertility of this 'sick' soil can be restored by merely heating it for an hour or two to a temperature approaching that of boiling water, the cost of which operation is considerably less than that of renewing the soil. In this case the uselessness of the used soil appears not to be due to the destruction of the nitrogen compounds, but to their retention in a condition unavailable for the plant. The nitrogen compounds have to be broken down to ammonia or nitrates before they can feed the plant; this process is effected by certain groups of bacteria, the numbers of which are limited in the sick soil by the excessive development of another group of soil organisms—protozoa, amœbæ, &c., that feed upon the bacteria.

We are only just beginning to take stock of all the changes in the soil materials that are effected by living organisms, some necessary, some competitors with the plant, some wasteful; the ultimate problem is to bring these processes under control in the field as well as in the laboratory. The antiseptic treatment of the land at large, in the way in which we can now clean up soils in pots, may seem an impossible dream, but not more impossible than the production of a heavily yielding weedless field of wheat would have seemed to

primitive man. Already much may be done to set up a better microflora and fauna in the soil by improving its physical conditions. The good effects of such processes as liming and drainage are largely due to the encouragement that is thereby afforded to the valuable organisms. Soil inoculation with such necessary bacteria as those which fix nitrogen when living in the nodules on the roots of leguminous plants has been widely attempted, but with very little practical success. The failures have generally been due to the fact that soils from which the nodule organism is absent are without it because of some chemical or physical defect; it is not sufficient merely to seed it with the organism; the soil itself must first of all be brought into a fit state to maintain its existence. The best of grass seeds would be wasted unless the land on which they are sown is first made clean and fertile. The amelioration of soils on their physical side, by bringing clay and silt to the sands, sand and coarse particles of various kinds to the clays, will eventually be taken up on a great scale, now that engineering has made it possible to move earth wholesale by cheaper means than by primitive spade and cart. I have seen a cold clay carrying miserable pasture converted into good market garden land by nothing more than the application of a thick layer of town refuse and ashes; only organisation is needed to make such processes economic, even when the immediate, and not the ultimate, return is reckoned.

From the point of view of manures we shall have to look forward to an ultimate scarcity of nitrogenous fertilisers; the exhaustion of sodium nitrate is only a question of time; the present sources of sulphate of ammonia will disappear with the coal, and the water power which is now giving us nitrate of lime and cyanamide will then be too precious to be used in making fertilisers. Even if the new process for the synthesis of ammonia proved as economical as is expected, we ought still to depend upon the natural processes of nitrogen fixation, and make the farm self-supporting as regards nitrogen at a high level of production. The clover crop in the rotation usually followed in England will, under present conditions, gather in enough nitrogen for the growth of about twenty-four bushels of wheat to the acre, an equal quantity of barley, and twelve tons of turnips. How can we similarly maintain production at a level of forty bushels of wheat, with other crops in proportion, yet without any nitrogenous fertiliser from outside?

A more immediate problem of the same kind is before the investigator; all around our great cities exist great market gardening industries, which have been built up by means of the cheap supplies of stable manure that were to be obtained therefrom. The market gardener close to London and as far afield as Bedfordshire, rendered thin sands and gravels fertile by using forty tons or more of London dung every year, but the advent of the motor car has curtailed, and will eventually put an end to, that supply, in which case how is the market gardening to be carried on? Nitrogen compounds and the other bare elements of plant food can be bought, but humus is also necessary to get these thin soils to yield a proper growth; what needs to be worked out is the cheapest and most effective way of utilising leguminous green crops and the other nitrogen-fixing organisms of the soil to maintain the fertility of such land, keeping in view the fact that it cannot be thrown out of productive cultivation for any length of time. What is needed is not a field experiment merely, but a discussion of a whole system of cultivation on the economic as well as on the scientific side. This suggests the general consideration that economic research in agriculture is still in its infancy. How often do we find close at hand two farmers, both good practical men, with entirely divergent views on the rotation to follow or the management of their stock, one swearing by early maturity and a forcing diet, the other by cheap if slow production. The advantage of one system over the other is not a mere matter of opinion and personal idiosyncrasy, it is possible to reduce it to terms of pounds, shillings, and pence. The prime necessity is the application to farming of a system of costs book-keeping, such as prevails in a well-organised business. It is possible to obtain such figures from a farm; the method is as yet perhaps too complicated for the ordinary farmer to follow, but as an instrument of investigation in the hands of a teacher at one of the agricultural colleges it may be made to yield results of great value both to the individual farmer and to all those who have to take more general views of agriculture.

Returning to the purely scientific aspects of research, the whole of existence is based upon the fundamental process by which the green leaf utilises the energy of the light falling upon it to split up the carbon dioxide of the atmosphere and transform it into those fundamental carbon compounds—sugars, starches, &c., which build up the substance of the plant. The animal creates nothing; it is only a transformer, and rather a wasteful one at that, of the compounds initially built up by the plant. Now, though the leaf is thus the prime creative force, it is yet a comparatively ineffective machine for dealing with the energy contained in the light, for it does not succeed in storing up in the shape of plant materials it produces as much as one per cent. of the energy that falls upon it a light, and in bright, tropical light the percentage utilised is even less. A steam engine, given a certain amount of energy in the shape of coal, turns out again about one-seventh of it in the shape of useful work; a gas or oil engine is an even more effective transformer. Can the duty of the leaf be increased so that it shall effect a greater production of dry matter for the amount of light energy it receives? We know very little as yet about even the sequence of chemical changes in the leaf beyond the fact that we begin with carbon dioxide and water and end with oxygen and some sort of sugar; we are beginning to acquire knowledge as to the extent the rate of change is affected by the supply of light, carbon dioxide, and water, and by the temperature. But we have now many examples in chemistry of reactions being speeded up or rendered more complete by means of some adjustment of the external conditions, so it is perhaps not too much to expect that this fundamental process of carbon accumulation may also be tuned up until the leaf becomes of greater efficiency than at present in producing tissue from the materials and energy supplied to it.

Probably the most immediate successes are before the plant-breeder, now that the application of the Mendelian theory has provided a method which renders both speedy and certain the processes of crossing and selection whereby the practical men of the past, working almost at haphazard, have already effected such enormous improvements in our cultivated plants. Among cereals, the qualities in demand, qualities which we know to be obtainable, are resistance to disease, stiffness of straw, and a large migration factor. We want to get rid of the plant-doctor, as it were; spraying and other prevention or curative treatments are both costly and of limited efficacy; the desirable method is to keep the plant free of disease by means of a naturally resistant constitution, and by establishing healthy conditions of soil and nutrition. As to stiffness of straw, the incapacity to stand up is probably the chief cause which limits the yield of corn crops in Britain wherever the farming is high. When a man keeps much stock, and buys cake either for his bullocks, or to feed to his sheep on the turnips, the land becomes so rich that the first corn crop will only stand up under exceptionally favourable weather conditions, and the farmer, so far from buying more fertiliser, cannot take full advantage of what is already in the soil. The land is often rich enough to yield 60 bushels of wheat to the acre, but it is exceptional that a crop of such weight will stand up so that it can be harvested by a self-binder. Mr. Beaven, in this section, has already dealt with migration; clearly it is a matter of great importance to the plant-breeder. Though the details have only been worked out for barley, the different varieties of any cultivated plant, wheat for example, are very much alike as regards their gross productive power—*i.e.*, the whole material grown weighs much the same in a dried condition. Even different crops produce much the same amount of dry matter when grown under the same conditions, this gross productive power being in all cases the similar product of the environment—*i.e.*, the result arising from the supply of food, water, light, temperature, &c. But granted that the different crops possess this same gross productive power, then their comparative usefulness depends upon the greater or less completeness with which they transform the crude material into products that may be used as food for man. In the cereals, for example, we want as much as possible of the original stuff manufactured by the leaf to be migrated later in the plant's life into the seed; of the total weight of the crop we want the largest possible proportion to be high-grade grain and not low-grade straw. Mr. Beaven has shown that the various varieties of barley do differ constantly in their proportion of grain to straw, and as, without

doubt, the same differences hold for other crops, this is a matter which must be watched by the plant-breeder.

Cereals are not, however, the only materials upon which the plant-breeder has to work; indeed, they are already among the most advanced of our domesticated plants, and the other farm crops require great improvement before they reach the level of wheat and oats. Sugar beet affords a most interesting case; by selection the percentage of sugar contained in the root has been raised by one-half. The total amount of material grown per acre remains, however, much where it was, because of the difficulty—the impossibility in fact as yet—of testing the yielding capacity of a seedling root, whereas its sugar contents can be measured with ease. The same difficulty is seen among our other root crops; such improvement as has been effected in the mangold, turnip, &c., has chiefly been in the shapeliness and habit of growth of the root, these alone being the characters that are apparent to the selector dealing with a group of seedlings. To some extent these may be correlated with total yield, but how little may be judged from the fact that the long red mangold, one of the very oldest varieties, is still the largest producer of dry matter and sugar per acre. The comparative yield of cereal varieties may be tested by the growth of a few hundred plants under rigorous conditions; some similar method will have to be worked out for root and fodder crops, before the plant-breeder can make much headway with them. Granted such a method, the plant-breeder has a fine, unexplored field before him in the leguminous and cruciferous fodder crops, and again in the fibre plants. Commercial flax, for example, is an entirely heterogeneous mixture of varieties, which never appears to have been subjected to the most ordinary selection. The fodder crops are matters of immediate importance, because the more intensive cultivation of the western side of Great Britain, where the high rainfall renders the growth of cereals a somewhat speculative industry, subject to loss at harvest and difficulties in the spring preparations for sowing, depends upon the elaboration of a system of farming based upon rapidly growing fodder crops. At present these districts produce milk, meat, and store stock, mainly from grass land that gets but little aid from the cultivator. The gross productive power of such land is small, and under the plough can be enormously raised, but arable farming has hitherto been avoided, except at times of abnormal prices, because of the risks attending harvesting. With improved fodder crops in place of grain a more profitable system of husbandry would replace the crops. Again, a new country like Australia will have to evolve its own fodder crops to suit the climate, and its own soil-regenerating plants.

Despite the fact that a given area of land will produce something like ten times as much human food of a vegetable nature as of meat and milk, if mere power of supporting life is considered, we may assume that the human race will not for a long time, if ever, turn to vegetarianism. Absolute pressure of population, supposing the maximum has to be supported that the land can be made to carry, would put an end to the preliminary conversion of vegetable into animal food, but it is probable that the dominant races will insist on remaining flesh-eaters even if that necessitates the limitation of their own numbers. However, the scientific man has at present little to say to this sociological question; his business is to make the animal a more efficient converter of coarse vegetable fodder into high-grade food. That there is plenty of room for development in this direction may be inferred from the facts that Professor Wood has called attention to in the paper he has recently submitted to this Section. What the grazier calls a good doer will lay on as fat and flesh twenty per cent. of the energy it receives in its food as against seven per cent. stored by a bad doer; here is an enormous margin for improvement if the average cattle are only brought up to the level of efficiency of the best. No one has yet worked out the most economic rate of feeding for different classes of live stock, the type of ration that will produce the largest amount of meat from a given weight of food, independent of the rate at which the increase takes place.

Granted the dependence upon research of the agriculture of the future if it is to meet the requirements of an increased population and a more advanced state of society, how can the required investigations best be organised? We may take it for granted that in some form or other the State must find the funds; in this connection at any rate there are no prizes for the private worker

such as would make agricultural research a tempting, even a possible, commercial speculation. There is a very limited field for patents or royalties; the breeder of a new crop variety can only exploit it with success if he has some big commercial organisation behind him, and even then a very few seasons place it in everyone's hands. The solutions to most of the great outstanding problems which I have outlined above could not be sold at a price, however much they might improve the output of every farmer. Indeed, there is this character about the advances which science may make in agriculture, and it explains the lack of interest in research exhibited by many hard-headed farmers, that the benefit comes to the community rather than to the individual. Farmer is competing with farmer, and if production is raised all round the price is apt to drop correspondingly, so that shrewd men who are doing very well as things are, are very content with their limited vision, provided the general ignorance remains unenlightened. However, we need not argue this point; every civilised country has accepted the necessity of maintaining agricultural research; even Great Britain, the last home of go-as-you-please, has fallen into line within the last year or two.

Assuming that the State pays, shall the immediate organisation and control of the work remain with the State direct, or be placed in the hands of semi-official bodies like the Universities? The character of the work required must settle this question. We may as well make up our minds at the outset that agricultural research is a very complex affair, which is going to arrive at commercial results very slowly. It deals with the fundamental problems of life itself; its problems mostly lie in the border country where two or more sciences meet, the debatable land which the man of pure science distrusts and affects to despise because there his clean and simple academic methods do not apply. Hence we have to attract to research in agricultural matters minds of the very best quality, men of imagination and determination, and give them scope and freedom to make the best of themselves. Now it has been recently claimed that the nation can only attract men of the necessary quality to research by instituting some system of prizes that shall be commensurate with the rewards that lie before the successful lawyer or business man who has embarked upon some competitive commercial career. I entirely dissent from this view; the quality of a man's work is not to be measured by the results it happens to attain, for results are often matters of luck, but least of all is to be measured by the amount of public attention the results arouse. It is in the nature of some kind of discoveries to excite the popular imagination, but these discoveries do not necessarily involve more credit to the discoverer than many others whose burial-place in this or that volume of 'Transactions' is only known to a select few. Once make publicity the criterion, and the scientific man is at the mercy of the boom and the advertisement; a good newspaper manner is more valuable than high thinking. Moreover, I would for the man of science say with Malvolio: 'I think nobler of the soul.' Give him a living wage and proper opportunities and he will give his best work without the added inducement of a chance of making his fortune. The real point is the living wage, and this does not mean the starveling price at which a man can be bought just after taking his degree. At present the career of research has some of the aspects of a blind-alley employment; the young man enters on it with enthusiasm, only to find ten years later that he has no market value in any other occupation and that he is expected to continue on an artisan's wage.

We have then to ensure the scientific man continuous employment; in such special subjects as agricultural science presents, we cannot trust to pick him for a particular job, and let him go when it is finished; there must be some reasonable sort of a career in investigation. The State cannot simply pay for results; men will not qualify for such precarious chances of employment. The great results come as incalculably as the great poetry, their value is similarly untranslatable into the cash standard, and though no provision of posts can ensure a supply of the finest flowers of the mind, routine science has this advantage over routine poetry, that it has some value and is even necessary to bring to fruition the advances of the pioneers. And when the great mind does happen to be born, he can only be turned to account if an organisation exists within which he can find opportunities for work. Now such an organi-

sation seems to be provided by the Universities rather than by the State. The type of man who makes an investigator is apt to be markedly individual; he can work better under the looser system of control that prevails in a University than under the official hierarchy of a Government department. The methods of research are anarchical, and ought to be continuously destructive of accepted opinions; when a Government department takes an official point of view, it is apt to insist on its being respected and not criticised by its officers on the strength. It has happened within recent years that a scientific man in Government employment has had to choose between his salary and his conscience, and though University laboratories are not always temples of free thought, their atmosphere is distinctly more open than that of a Government office. The type of man most fitted for research is more attracted by a University than a department; he wants his value to be measured by the quality of his scientific work, rather than by his official adaptability. But the greatest objection to making research a function of Government is that it is of necessity subjected to an annual detailed justification of its expenditure to a non-expert legislative body. When one reads the cross-examination of this or that investigator by the Committee of Public Accounts of certain States which maintain departments of agricultural research, one realises the hopelessness of expecting the slow, far-reaching scientific work that ultimately counts from men who are subject to such an annual criticism. The almost complete sterility of certain State organisations for research on a great scale can be absolutely set down to the call that prevails for an annual report of results which seem to pay their way; only a talent for advertisement comes to the front under such a régime. Of course, a State must maintain laboratories which undertake a certain amount of investigation in connection with its duties in the control of disease, &c., but, though it may be difficult to draw a defining line between research that arises out of administration and research in pursuit of knowledge, the distinction is easy to make in practice. For example, the State needs a veterinary laboratory for the purpose of checking the conclusions upon which the administrative regulations regarding this or that disease are based, and of testing serums, vaccines, and the like, but it would prove false economy in the end to entrust to this official institution the sole responsibility for investigations into animal diseases.

Another advantage that arises from entrusting agricultural research to the Universities is that thereby one obtains the advice, and often the active co-operation, of men in the departments of pure science. I have already indicated how complex are the questions that agriculture raises; the man who is working out soil problems may find one day that he is brought to a standstill by some physical or even mathematic difficulty he is not competent to deal with, on another occasion he may wish to consult a geologist, or again a zoologist. No soil laboratory pure and simple can afford to have men of all these qualifications upon its strength, but if it is attached to a University, its men are naturally in constant contact with other specialists from whom they may informally obtain the assistance they need. A special purpose laboratory must suffer if it is isolated from the general current of science, and this is particularly true of agriculture with its many contacts, and the natural inclination to locate its institutions in the country. Some link must be maintained between the research institution and the practical farmer, not so much for the sake of the latter, because he is rarely in a position to utilise directly, or even to understand, the work of the investigation, but in order to keep the work real and non-academic. Even from the purely scientific point of view the most fruitful lines of research are those suggested by practical life; many effects that prove to be of fundamental importance to theory, only become apparent in the large-scale workings of the commercial undertaking. The contact with farming that the research-worker needs should be provided by his association with the University department that is teaching agriculture and advising the farmers of its district; thus is established the connection that on the one hand brings the farmer's problems to the investigators, and on the other translates the investigators' results into practical advice. As I see it, the ideal organisation of research in agriculture is to associate a more or less specialised institution for the investigation of a particular class of problem with a University possessing an agricultural department, which is also charged with extension work by way

of lectures and advice within its own sphere of influence. How specialised the institution may become must depend upon the numbers of Universities available, but there is a real economy in specialisation, in inducing each institution to throw its whole strength into one line of work, for Universities, like men, cannot afford to be Jacks of all trades.

Many of my hearers may think I am sketching out a very ambitious and extensive programme about which the only certainty is the creation of a considerable number of salaried posts for men of science, but when I think of the futilities upon which so much public money is spent in every country, I am almost ashamed to justify the expenditure by pointing out that an increase of ten per cent. in any one of the staple crops of a country, such an increase as is well within the powers of the scientific man to effect in no great length of time, would pay over and over again for the organisation I have indicated. Even if the research went on for the sake of knowledge alone, every nation is able to allow itself a certain amount of intellectual luxury. Moreover, to return to my original text, it is only by the aid of agricultural science that the world is ultimately going to be allowed to enjoy any luxuries at all; as the fundamentally agricultural basis of society again becomes apparent, the one thing that will save it from sinking down into a collection of families each wringing a bare subsistence from a tiny plot of ground will be the application of the fullest knowledge to the utilisation of the land.

NARRATIVE AND ITINERARY OF THE AUSTRALIAN MEETING.

Preliminary Arrangements.

The Australian Invitation.—The possibility of a British Association Meeting in Australia was discussed there as early as 1884, and again in later years, but the time was not yet ripe. The question was once more raised, however, early in 1909, when Sir Charles Lucas, late of the Colonial Office, was visiting Australia; and it was brought forward publicly on May 3, 1909, at a meeting of the Council of the University of Melbourne, by Dr. J. W. Barrett. As a result of his motion a committee was appointed in that University to formulate a scheme and take all necessary preliminary action. This committee, of which the President-elect of the Australasian Association for the Advancement of Science (Professor Orme Masson) was Chairman, sought and obtained the cordial approval of its proposals by the other Australian universities and the leading scientific societies, and local committees were formed to co-operate with it in Sydney, Adelaide, and other centres. It was decided that the Commonwealth Government should be asked to father the invitation to the British Association and to grant a sum of £10,000 towards defraying the overseas expenses of the visit, that the State Governments should be asked to give free passes over their railways, and that hospitality and other expenses should be guaranteed by local authorities and the general public. It was further decided that the invitation should be given for 1913 or 1914, and that, following the example of the South African Meeting in 1905, the Association should not confine itself to one centre, but should visit each of the States in turn.

Professor J. W. Gregory, who was visiting Melbourne, was informed of the Committee's proposals, and was thus enabled a few weeks later to bring the project under the notice of the General Committee of the Association at the Meeting in Winnipeg (1909), where it was informally discussed with encouraging results.

On December 16, 1909, a deputation, representing all the Australian bodies interested, waited on the Prime Minister, Mr. Alfred Deakin, who expressed cordial approval of the scheme, and promised to give it strong support. When, shortly afterwards, there was a change of Government, Mr. Andrew Fisher, who succeeded Mr. Deakin as Prime Minister, took the matter up with equal cordiality, and under his administration the proposals received the sanction of the Commonwealth Parliament. The State Governments were also approached, and promised their support, especially in the matter of the free use of the railways. Finally instructions were given by the Prime Minister to Sir George Reid, High Commissioner for Australia, and Professor Orme Masson to convey the invitation from Australia to the Association, and

they did so at the meeting of the General Committee held in Sheffield on September 2, 1910.

In anticipation of the invitation, the General Secretaries of the Association, in June 1910, had issued a circular letter addressed to Members of the General Committee and other representative Members, of professorial and similar standing, asking whether the recipients foresaw any possibility of attending a meeting in Australia or not. The proportion of Members who answered this inquiry in the affirmative was sufficient to warrant favourable consideration of the invitation. The General Committee unanimously accepted the invitation (after some discussion in private), and chose the later year offered (1914), having in view the consideration that the Association had twice in recent years (1905 and 1909) met outside the United Kingdom.

Commonwealth Grant.—As already indicated, the Commonwealth Government guaranteed from the outset a substantial sum to be devoted exclusively towards the expenses of the voyage overseas incurred by representative scientific Members to be selected and invited by the Council of the Association. The General Officers of the Association, judging (as events proved, rightly) that a representative body could be gathered together larger than that for which the sum originally proposed would have afforded sufficient provision, took advantage of the occasion of Their Majesties' Coronation, when members of the Commonwealth Government were present in London, to discuss this matter with them. The suggestions then made from the point of view of the Association were received in the most generous spirit, and the Commonwealth Government subsequently increased its grant to £15,000, which was placed at the disposal of the Association under no other condition save that (in the words of a cablegram received by the High Commissioner from his Government in November 1912, and communicated by him to the Council of the Association) it was 'to cover passages of not less than 150 official representatives, including selected Dominion and foreign scientists.' The allocation of this sum formed, as will be presently seen, the most important function of a Committee appointed by the Council to deal with arrangements for the Meeting; it may be stated here that the actual number of representative Members who benefited under the grant was 155—approximately one-half of the Overseas Party.

Letter to Universities.—No great amount of preliminary work was found necessary in London during the Council's sessions in 1910-12, though in June 1911 the Council authorised the General Secretaries to address a letter to universities and other educational institutions in the United Kingdom, requesting the authorities to do what lay in their power to relieve of examining and other duties, in July and September 1914, any members of their teaching staff who might contemplate attending the Australian Meeting. The response to this request was favourable in the majority of cases, and very few instances came subsequently to the knowledge of the Association officers of Members prohibited by professional duties from accepting invitations to attend the Meeting. A letter in similar terms was sent independently by the Federal Council in Australia.

AUSTRALIAN ORGANISATION, 1912-13.

Local Committees and Officers.—Early in 1912 it was recognised in Australia that more definite and official machinery was now required for the organisation of the Meeting than had sufficed in the earlier stages. After consultation with those already chiefly concerned, the Prime Minister, Mr. Fisher, therefore gave instructions to

Professor T. W. E. David, C.M.G., F.R.S., Sydney,
Professor Orme Masson, F.R.S., Melbourne,
Professor E. C. Stirling, C.M.G., F.R.S., Adelaide,
Professor B. D. Steele, D.Sc., Brisbane, and
Sir J. W. Hackett, K.C.M.G., Perth,

to take the necessary steps. Each was asked to consult with the Governor of his State, the Premier, and the municipal and university authorities, and then to form a large General Committee for his State, with special sub-committees and an executive committee, and to arrange for the appointment of delegates, who, together with representatives of the Commonwealth Parliament, should form a Federal Council or central executive. At the same time the Prime Minister signified his approval of a suggested programme and itinerary for the Meeting, of the proposal mentioned above to increase the Commonwealth grant from £10,000 to £15,000, and of a suggestion to appoint a responsible official Organising Secretary. As a result of these instructions large committees were formed and met in each centre, and public interest was widely aroused. Each General Committee was under the presidency of the State Governor, and the following executive officers were appointed:—

NEW SOUTH WALES:
Chairman, Professor T. W. E. David, C.M.G., F.R.S.
Secretary, J. H. Maiden, F.L.S.
Treasurer, H. G. Chapman, M.D.

VICTORIA:
Chairman, Professor Orme Masson, F.R.S.
Secretary, Professor Baldwin Spencer, C.M.G., F.R.S.
Treasurer, Charles Bage, M.D.

SOUTH AUSTRALIA:
Chairman, Professor E. C. Stirling, C.M.G., F.R.S.
Secretary, Professor Kerr Grant, M.Sc.
Treasurer, Thomas Gill, I.S.O.

QUEENSLAND:
Chairman, Professor B. D. Steele, D.Sc.
Secretary, T. E. Jones, B.A.
Treasurer, Professor H. J. Priestley, M.A.

WEST AUSTRALIA:
Chairman, Sir Winthrop Hackett, D.Sc., K.C.M.G., who was succeeded later by the Hon. W. Kingsmill, B.A., M.L.C.
Secretaries, Professor W. J. Dakin, D.Sc., W. Catton Grasby, F.L.S.

Besides these, many other individuals did invaluable work before and during the Meeting as officers or members of executive or of special sub-committees.

The Federal Council held its first meeting at Melbourne in November 1912, under the presidency of the Prime Minister, Mr. Fisher, with Mr. M. L. Shepherd as Secretary. A smaller Federal Executive (Professor Masson, Chairman) was then appointed, and the office of Organising Secretary was offered to and accepted by Mr. A. C. D. Rivett, D.Sc., of the University of Melbourne. Dr. Rivett's work in England during 1913, and subsequently in Australia, is referred to elsewhere. For fifteen months he devoted himself entirely to the duties of his office, and it is recognised by all concerned that the success of the Meeting was very largely due to him. In June 1913 Mr. Joseph Cook succeeded Mr. Fisher as Prime Minister, and acted as President of the Federal Council until the close of the Meeting.

From the end of 1912 till the Meeting in August 1914 a great deal of work devolved on the State Committees and on the Federal Council and its Executive, and many meetings were held. There was constant communication with the office of the Association in London and with the Governments of the Commonwealth and the States. Some of the chief matters dealt with are referred to below.

Local Costs of the Meeting.—Besides its contribution of £15,000 for overseas travelling, the Commonwealth Government defrayed all the Organising Secretary's expenses and those connected with the work of the Federal Council. It also contributed largely to certain of the official entertainments during the Meeting. The State Governments, besides undertaking the whole cost of Members' railway travelling in Australia, contributed each a large sum towards the general expenses of the local meeting.

Hospitality.—In each State a special Committee undertook to provide for the reception of each visiting Member as a guest either at a private house or at a club or hotel. Apart from the executive officers already named, the following may be specially mentioned in this connection:—

Adelaide: Sir Samuel Way, Bart.
Melbourne: Mr. John Grice, Mr. D. J. Mahony.
Sydney: Lady McMillan, Mrs. Ashburton Thompson.
Brisbane: Sir Pope Cooper, Mr. F. Philpott.

Excursions.—These were planned and carried out by special local Committees, with valuable assistance from the railway authorities and from the Automobile Clubs. The following, with the Executive officers, were mainly responsible for the Excursion programmes:—

Perth: Professor Woolnough, Mr. C. Andrews.
Adelaide: Mr. H. Angas Parsons, M.P.
Melbourne: Dr. J. W. Barrett, C.M.G., and Professor E. W. Skeats, D.Sc.
Sydney: Mr. Justice Docker, Mr. F. C. Govers.
Brisbane: Sir Arthur Cowley, Mr. T. C. Troedson.

It is unnecessary to mention the many organisers and leaders of separate excursions.

Railway Travelling.—A great deal of organisation was necessary to provide suitably for the simultaneous transport of so large a party of visitors in special trains, with sleeping accommodation and arrangements for meals, between the capital cities of the different States, which are separated by distances of many hundreds of miles. Arrangements had also to be made for the collection and separate transport of Members who arrived at various Australian ports apart from the main party, and for the return of Members to various ports after the conclusion of the Meeting. The handling and transport of large quantities of luggage had also to be planned. In connection with all such work the Committees had invaluable assistance from the State Railway Commissioners and their subordinate officers, and were specially indebted to the Chief Victorian Commissioner, Mr. W. Fitzpatrick.

Facilities for Extended Travel.—Under this head may be included some of the longer organised excursions which were carried out during or immediately after the Meeting, such as those to the Broken Hill Mines and to Tasmania. But in addition the Federal Council undertook to provide facilities for any Member who might desire to devote himself for a time to special scientific work in Australia. Advantage was taken of this by not a few, though the War undoubtedly interfered with the plans of many.

Accommodation for the Meeting.—All the Australian universities placed their buildings unreservedly at the disposal of the Committees. In the chief centres arrangements were made to utilise the great halls as reception rooms, the Unions and club-rooms as luncheon rooms, etc., and to house each Section in a suitable lecture theatre with adjacent committee rooms.

Work of the Sections.—Two local Secretaries were appointed for each Section, one in Melbourne and one in Sydney, for the purpose of providing suitable programmes of local work (as mentioned later) and making other arrangements in consultation with the Recorders.

Handbooks.—A number of illustrated scientific handbooks were prepared in view of the Meeting. The chief of these was the 'Federal Handbook on Australia,' consisting of a series of monographs written by selected specialists. This volume was edited by the Commonwealth Statist, Mr. G. H. Knibbs, C.M.G., and published by the Commonwealth Government. A separate volume on similar lines, but of more limited scope, was issued by each State. A copy of each was presented to every visiting Member, and most of them were distributed in London beforehand. The Editors of the State Handbooks were:—

South Australia: Mr. D. J. Gordon and Mr. V. H. Ryan.
Victoria: Mr. A. M. Laughton and Dr. T. S. Hall.
New South Wales: Mr. R. H. Cambage and Mr. W. S. Dun.

The Western Australian and Tasmanian books were in the hands of Committees. The Queensland book was a Government work published some time previously.

Home Organisation.

The Home 'Australian Committee.'—By the time of the Dundee Meeting, 1912, an outline programme of the Australian Meeting was in being, and in the subsequent session of the Council Australian arrangements began to find an important place. In November 1912 the Council appointed a Committee, 'to assist the President and General Officers in matters regarding the Meeting in Australia,' consisting of Professors A. Dendy, J. W. Gregory, A. Liversidge, and E. Rutherford, to whom were subsequently added Professor W. Bateson and Professor C. J. Martin, while from October 1913 onward the Sectional Presidents appointed for the Meeting were also taken into consultation. This 'Australian Committee' held fourteen meetings between December 1912 and March 1914. As has been indicated, its principal work was the allocation of grants out of the Commonwealth Fund towards the overseas expenses of Members. It was known to be the view of the Australian authorities that the invited representative Members should be involved in as little expense as possible beyond incidentals, and therefore it was determined that grants should be made at a uniform rate of £100 (the reduced return fare, first class, by the Suez route, excepting certain special cases, such as that of invited members travelling from countries less distant than the United Kingdom from Australia, to whom smaller grants were made. By February 1913 the Council had already determined the names of a majority of the Sectional Presidents whom it was intended to appoint for the Australian Meeting; the names of certain other official and leading members of the 'Overseas Party' (as it came to be termed) for that Meeting were already known, and the Committee was thus able to allocate some part of the grants forthwith. It then became essential that the Committee should be informed how far the demand for grants was likely to exceed the supply. In June 1913, therefore, members of the General Committee were asked whether they would join the invited party if grants were offered them; a selection was found to be necessary from the list of names thus obtained, and this task occupied the Committee during the ensuing autumn, from the time of the Birmingham Meeting onward, while later on it became possible to draw upon outstanding names in order to fill vacancies which from time to time, through various individual causes, occurred in the 'grantee' list. No grant was left unfilled.

Foreign and Dominions Representatives.—Before leaving the subject of the selection of the invited Members, reference may be made to the invitation of representatives from foreign countries, the United States of America, and British overseas Dominions other than Australia. It was the wish of the Australian authorities (as appears from the cablegram quoted above) that the Overseas Party should include such representatives; the list of Members of the Association (especially that of Honorary Corresponding Members) supplied in itself a wide field for invitation; in addition, other names were suggested by the executives in the various States of the Commonwealth, and others, again, by the representatives of the various Sections of the Association on the Committee at home. It will be readily understood that the number of

invitations issued to foreign representatives was large in proportion to the number of those who were able to accept, but eventually the Overseas Party included altogether 1 Canadian, 10 American, 3 South African, 8 German, 1 Russian, 1 Polish, 2 Italian, 1 Swedish, and 5 Danish members and guests, and also 3 from British India.

Number of the Overseas Party.—Apart from the allocation of grants, the question of the total number of the Overseas Party demanded careful consideration. The Council had not the power, even if it had felt the inclination, to impose any direct limitation upon the number of Members attending the Meeting. On the other hand, the Australian authorities, while offering very extensive facilities in the direction of free railway travelling and hospitality up to a number largely in excess of the number of the grantees and other Members specially invited, were obviously compelled to take into consideration the number for whom it would be possible to provide special trains and find hospitality. Moreover, it was essential that the number and composition of the Overseas Party should be known at as early a date as possible, in order that the local organisation might be carried out with a reasonable knowledge of the requirements of the party. A general circular concerning the Meeting was therefore issued to Members in October 1913; replies from those who intended to attend the Meeting were invited by November 1 (excepting the case of Members residing abroad), and it was made clear that any delay in replying might involve a Member in difficulties and inconveniences for which no responsibility could be accepted. In December 1913 the Council decided that Members whose intimations of intention to attend were qualified by doubt, or were received late, could be guaranteed no special facilities in Australia, and that no new Members should be enrolled for inclusion in the Overseas Party, except at the discretion of the Committee, as in the case of an applicant whose attendance might be deemed to be of special importance on scientific grounds. It remained open to Members to proceed to Australia, and take part in the Meeting, at their own risk so far as concerned the facilities already mentioned: a few did so. But the provisions above detailed succeeded in their object of ensuring that no serious difficulties should be ultimately encountered by the Australian authorities in dealing with the transport and accommodation of the party. No division of the party was made into 'official' and 'non-official' classes for purposes of differential treatment in these departments. The total number of the Overseas Party was 300. No Associates were enrolled in England for this Meeting.

Arrangement of Sectional Programmes.—The Council held a special meeting on October 17, 1913, in order to appoint sectional officers, and thus enable the Organising Sectional Committees to get to work as early as possible. It was agreed that as it would be barely possible, in view of the great distance, for these Committees to receive and consider papers offered by Australian scientific workers, local committees in Australia should undertake the responsibility of selecting these, working on the rough rule that local communications should not generally occupy more than one-third of the time available for sectional work, though in such sections as Geology, Zoology, Geography,

Anthropology, Botany, and Agriculture this proportion might be increased to one-half.

Special Membership Terms in Australia.—At the same meeting of Council the General Treasurer brought forward proposals (which had been referred to the Council by the General Committee Meeting at Birmingham) regarding the cost of membership subscriptions for persons joining locally in Australia. These proposals, which were adopted, laid down that for persons attending meetings in any two or more centres the price of membership tickets should remain unaltered, but that for persons attending at any one centre only the price of new annual membership should be £1 only, including the right to receive the annual volume free, and that there should be an Associate's fee of 10*s.*, at Adelaide and Brisbane only. The main reason for these special arrangements lay in the fact that at no one centre in Australia would there be undertaken the equivalent of a complete programme of a meeting under normal conditions. Any ticket issued in Australia to a lady was made transferable to another lady under the same conditions as those under which it was issued. That these concessions were appreciated was proved by the very large local membership enrolled, to which reference is made later in this narrative.

Visit of the Australian General Organising Secretary to England.—During the period from July to December 1913, during which the majority of the arrangements hitherto discussed were undertaken, the home officers and Council had the benefit of the presence and collaboration of the Australian Organising Secretary, Dr. A. C. D. Rivett, who was sent on a special mission to England in connection with the arrangements. During his visit he was able to attend the Meeting of the Association in Birmingham in September 1913, and thus to obtain a full knowledge of the details of organisation under normal conditions. He was also able to become personally acquainted with a large proportion of the intending visitors to Australia. For the rest, he worked in intimate relationship with the Assistant Secretary at the London Office, and together they traversed, so far as possible, the whole field of the organisation, with the guidance and approval of the General Officers, the Committee, and the Council. The sum of their discussions was finally embodied in a memorandum, dealing in detail with such topics as the arrangements to be made for the reception of the party on arrival at each centre, with the character and method of distributing to each member information lists advising of these arrangements and directions as to transport, with the handling of baggage, and in connection with this, and for other purposes, the allocation of a distinguishing number to each individual member of the Overseas Party, with the fitting and organisation of service in the Reception Rooms, with the requirements of the Sections, with the division of work between the London and the local offices in regard to the issue of tickets, programmes and other matter, and so forth. They also endeavoured to define the various topics on which they would have to exchange information by mail during the period January to June 1914 (*i.e.*, after Dr. Rivett's return to Australia), and in some instances the particular

mails by which such information should be sent were specified. These plans, tentative as they were, succeeded so far that the use of the cables was necessitated only six times from London to Australia and five times in the opposite direction during the period named.

At the last meeting of Council before Dr. Rivett's departure from London (December 5, 1913), it was resolved that the thanks of the Council be expressed to him for the assistance he had rendered in connection with the arrangements for the Australian Meeting during his visit to England, and to the authorities in Australia under whose direction he had paid this visit.

The Assistant Secretary left London early in June 1914 to join the General Organising Secretary in Australia, when they visited together all the centres (except Perth) before the beginning of the Meeting, as Dr. Rivett had already done on previous occasions.

Shipping Arrangements.—In the meantime the work of the officers at home was concerned mainly with making up the Overseas Party (as has been shown already), and those sections of it which were to visit Western Australia in advance of the main body, and New Zealand after the conclusion of the Meeting in Sydney.[1] With the exception of the arrangement with the Orient Company, which was originally made by the Australian authorities, negotiations with the shipping companies as to special fares and arrangements for Overseas Members had been conducted, and continued to be so, principally from the London Office, and may be briefly summarised here:—

(1) *Via* Suez, return, 1st class £100 (refund £35 if return half of ticket unused). Second class £65. Orient and P. & O. lines (return tickets interchangeable between these); also Norddeutscher Lloyd line.

(2) *Via* Suez outward; return *via* Malay Archipelago to Colombo and Suez, 1st class £130. Burns, Philp and other lines locally through Archipelago.

(3) Round the world *via* Atlantic, Vancouver, or San Francisco, and Suez, £120; or *via* South Africa instead of Suez, £100. All trans-Atlantic lines; Canadian Pacific, Union Steamship Co. of New Zealand, and Oceanic trans-Pacific services.

(4) North American routes, return, 1st class £115 10*s*.

[1] **Projected Visit to New Zealand.**—An invitation was received in 1911 from the High Commissioner for New Zealand, on behalf of his Government, for some of the Members visiting Australia to proceed to the Dominion, and it was subsequently arranged, after consultation with the Australian authorities, that a party should leave the Meeting of the Association at the conclusion of the Sydney session, and proceed to New Zealand to take part in scientific meetings, excursions, &c., together with representative Canadian and American men of science invited by the Dominion authorities. A committee under the chairmanship of the High Commissioner, and including representatives of the Association, selected in London a number of Members for invitation, and to receive grants in aid of additional expenses incurred by the visit out of a fund provided by the Dominion Government, while Professor T. H. Laby (of Victoria College, Wellington) and others concerned themselves with arrangements in New Zealand. But while the Meeting of the Association was in progress it was announced that the arrangements for the visit to New Zealand had unhappily proved in great measure abortive, owing to the effects of the European War.

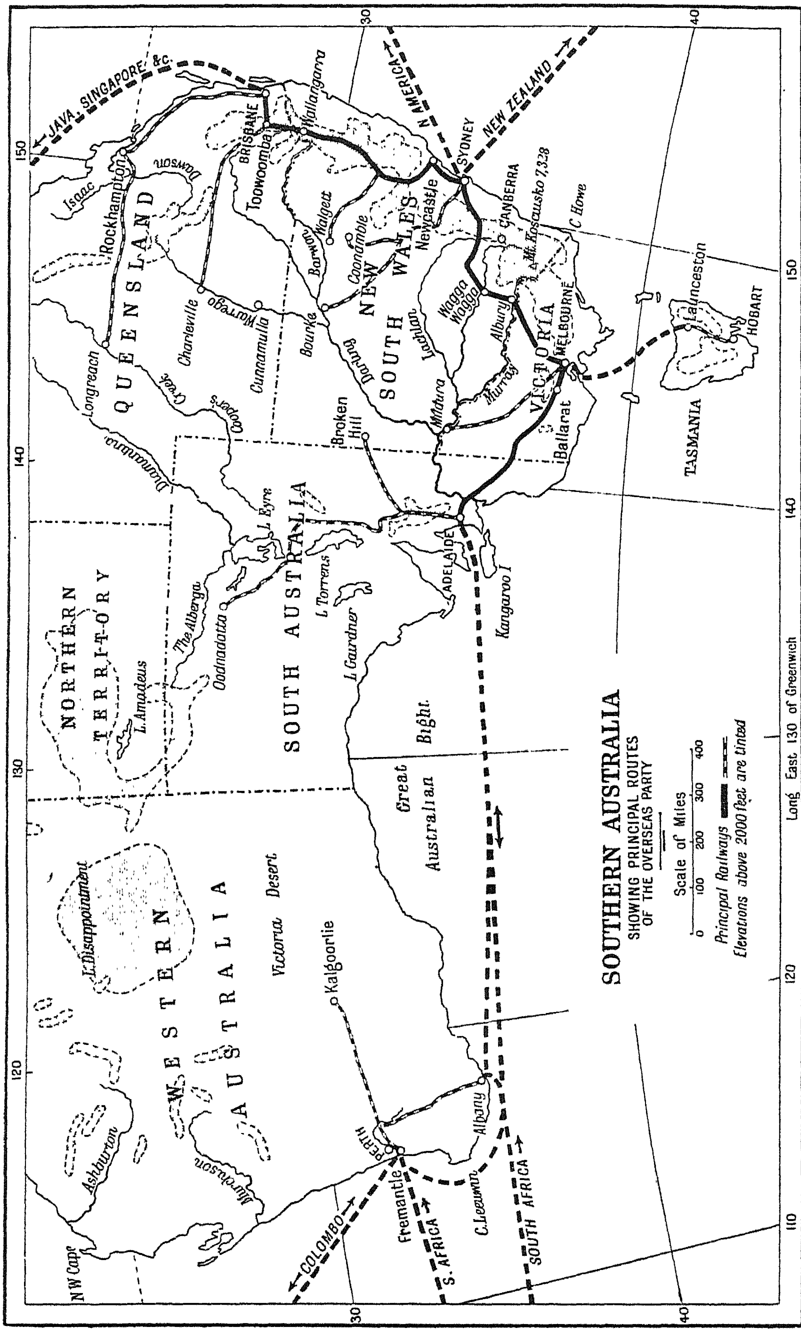
SOUTHERN AUSTRALIA
SHOWING PRINCIPAL ROUTES OF THE OVERSEAS PARTY
Scale of Miles
0 100 200 300 400
Principal Railways
Elevations above 2000 feet are tinted
Long East 130 of Greenwich
G W Bacon & Co Ltd 127 Strand London
JAVA, SINGAPORE &c.
N AMERICA
NEW ZEALAND
COLOMBO
S. AFRICA
SOUTH AFRICA
NORTHERN TERRITORY
QUEENSLAND
NEW SOUTH WALES
VICTORIA
SOUTH AUSTRALIA
WESTERN AUSTRALIA
TASMANIA
Great Australian Bight
Victoria Desert
Brisbane
Toowoomba
Wallangarra
Rockhampton
Longreach
Charleville
Cunnamulla
Bourke
Walgett
Coonamble
Newcastle
Sydney
Canberra
Mt. Kosciusko 7,328
C Howe
Wagga Wagga
Albury
Melbourne
Ballarat
Mildura
Broken Hill
Adelaide
Kangaroo I
Launceston
Hobart
Oodnadatta
L Eyre
L Torrens
L Gardner
L. Amadeus
L. Disappointment
Kalgoorlie
Perth
Fremantle
Albany
C. Leeuwin
NW Cape
Ashburton
Murchison
Isaac
Dawson
Warrego
Barwon
Darling
Lachlan
Murray
Cooper's Creek
Diamantina
The Alberga
Great Australian
30
40
110
120
130
140
150

FIG. 1.

(5) *Viâ* South Africa, return, 1st class £75. Blue Funnel and Aberdeen lines.

Various alternative routes were offered by the above and other companies: it is unnecessary to detail them here, but it may be stated that the companies generally met the requirements of the party very liberally. The vessels and routes which carried the largest numbers of Members on the outward journey were—(1) the Orient R.M.S. *Orvieto*, sailing from London on July 3 *viâ* Suez and arriving in Adelaide on August 8, which also, by special arrangement with the Company, carried most of the Western Australian advance party forward from Fremantle to Adelaide; (2) the Blue Funnel s.s. *Ascanius*, which, by special arrangement, sailed from Liverpool on June 22, *viâ* Cape Town, and called at Fremantle on July 28, conveying the majority of the Western Australian advance party; (3) the Aberdeen s.s. *Euripides*, which (making her maiden voyage) left London on July 1 and called by special arrangement at Adelaide on August 7. Some Members reached Australia by way of the Pacific and Sydney, and some made extended stays in Western Australia or elsewhere, in advance of the Meeting, for purposes of research.

Communications to Members.—As Members of the Overseas Party were thus able to pursue their individual inclinations as to routes for the outward voyage, and as it was essential to the organisation that each Member's route and date of arrival should be known, it was necessary, during the early months of 1914, for the London Office to request (if not to importune) the Members to state their intentions. For the most part Members appreciated this necessity, and only in isolated instances were the organisers at home and in Australia compelled to make arrangements in ignorance of the actual intentions of Members who failed to realise the inconvenience which they caused by refraining from answering inquiries, or even neglecting to give information that their intention to attend had been cancelled. In addition to such inquiries it was necessary to furnish all or some of the Members, during the period November 1913—June 1914, with vouchers for reduced steamship fares, information concerning the visits to Western Australia, Tasmania, and Broken Hill, and the projected visit to New Zealand, invitations to join these parties, information concerning arrangements with shipping companies, scientific investigations to be made during the voyage, &c., and, at a late stage, programmes of final general arrangements, and of sectional arrangements, together with a list of the Overseas Party and the route adopted by each Member so far as known, with which was incorporated a dated memorandum book covering the period of the stay in Australia. Membership tickets and special luggage labels (bearing the Members' distinguishing numbers) were also issued from the London Office. Taking all these matters into consideration, it is not impossible that some Members may have received during this period as many as twenty-eight printed programmes or other circular communications, in addition to individual correspondence with the office, which attained (in some instances) substantial dimensions. Indeed, the total number of programmes, circulars, letters, &c., issued from and

received by the London Office in connection with the Australian Meeting is estimated to have exceeded 24,000, and in this connection it is necessary to remember that the London Office was only one of a number of centres where official business connected with the Meeting was regularly carried on. Some account of the work in these other (Australian) centres may now be given.

Australian Organisation, 1914.

On the return of the Organising Secretary from England in February 1914 an office was established in the Prime Minister's Department, Melbourne, which served to keep the work done in each capital city in touch with that of the London office. Periodical visits were made to the other States by the Organising Secretary.

Copies of the memorandum prepared in London by the Assistant Secretary and the Australian Organising Secretary were circulated to the responsible officers in each centre. Specific local conditions sometimes necessitated trifling alterations in the suggested scheme of organisation, but for the most part the general plan was closely adhered to, it being recognised fully by all executive officers that the advantage of uniformity was very great, and would be particularly appreciated by Overseas Members when moving rapidly from one capital to another.

Executive Committees, together with sub-committees dealing with hospitality, excursions, and scientific business, met frequently after the beginning of April. The main work of the Hospitality Committees, after securing hosts, lay in the allocation of guests to hosts. As the time of the Meeting approached it was, of course, inevitable that many changes would occur in the list of visiting Members: the consequent continuous readjustments in hospitality arrangements were sometimes considerable. As will be seen later, this was particularly the case in Brisbane, where the abandonment at the last moment of the Meeting in New Zealand necessitated a rapid alteration of most of the Committee's arrangements.

The Excursions Committees, after settling the localities to be visited, were required to determine the numbers of overseas and local Members respectively, for whom provision could be made. The general principle was accepted throughout that the excursions were primarily, and in many cases solely, for the visitors. Thanks to the keenness of the Members of the Overseas Party there were scarcely any cases of arrangements failing through lack of visitors. Very great assistance was rendered by Government officials throughout the work of all Excursions Committees.

In each centre reports on the work of executive and sub-committees were presented periodically to the large General Committees.

Local Membership.—It was fully recognised in Australia that the possibility of the Association continuing during 1914-1915 its work of financially aiding original scientific investigations depended largely upon securing a long roll of local Members. This fact was made widely known in the Press, and the determination was expressed that the visit to Australia should not result in any lessening of the Association's activities. Even better results would have attended efforts to gain local

Members had there not been a temporary cessation of enrolments directly after the outbreak of war.

THE MEETING IN AUSTRALIA.

Western Australia.

Outward Voyages of Advance Party.—About seventy visiting Members, who became known collectively as the Advance Party, visited Western Australia for a stay in most cases of a week, but in some of a fortnight or even longer, before the main party arrived in Australia. Of those who stayed a week most arrived by the Blue Funnel steamer *Ascanius*, which made a special call at Fremantle (the port of Perth, W.A.) in order to land the party. A few arrived by the P. & O. mail steamer (*via* Suez), which reached Fremantle on July 28, the same date as the *Ascanius*.

A good deal of research definitely planned in relation to the Australian Meeting was carried on during the voyage out by some members of the Advance Party. On the *Ascanius*, for example, Professor W. G. Duffield made observations on the variations in the force of gravity over the ocean, and Professor W. A. Herdman examined and preserved samples of the plankton from the surface waters running continuously through fine silk nets, day and night, between Liverpool and Fremantle. Both these researches were very materially promoted by the managers of the Blue Funnel Line, who most generously fitted up a special laboratory for each of these purposes and gave special facilities for carrying on the work. Research was also carried out on other routes, and on the return voyages.

Public Lectures, &c., in Western Australia.—Some little delay in the arrival of the *Ascanius* on July 28 interfered in some measure with the arrangements for that day, but that evening Professor W. A. Herdman, F.R.S., was able to give the first Association lecture in the Museum Lecture Hall at Perth, with His Excellency the Governor of Western Australia, Sir Harry Barron in the chair, the subject being 'Why We Investigate the Ocean.' After expressing the gratitude of the visitors for their reception in Western Australia and their appreciation of the labour which had been expended throughout the centres to be visited, in preparation for the Meeting, Professor Herdman approached the subject-matter of his lecture principally from the point of view of the establishment and development of marine fisheries, with especial reference to the potentialities of Australian waters. He also discussed the investigation, exploitation, and regulation of the fisheries of North-western Europe, illustrating by means of lantern slides the methods there employed, while another series of slides illustrated the reproduction and growth of the more valuable fishes found in British waters, and their dependence upon the more minute organisms forming the plankton of the ocean.

Subsequently official lectures were given in Perth as follows:—

July 31, at the Museum, Professor A. S. Eddington, F.R.S., on 'Stars and Their Movements,' the Lieutenant-Governor, Sir Edward Stone, in the chair. The lecturer discussed the census of stars and their classification according to age by means of their spectra, of which

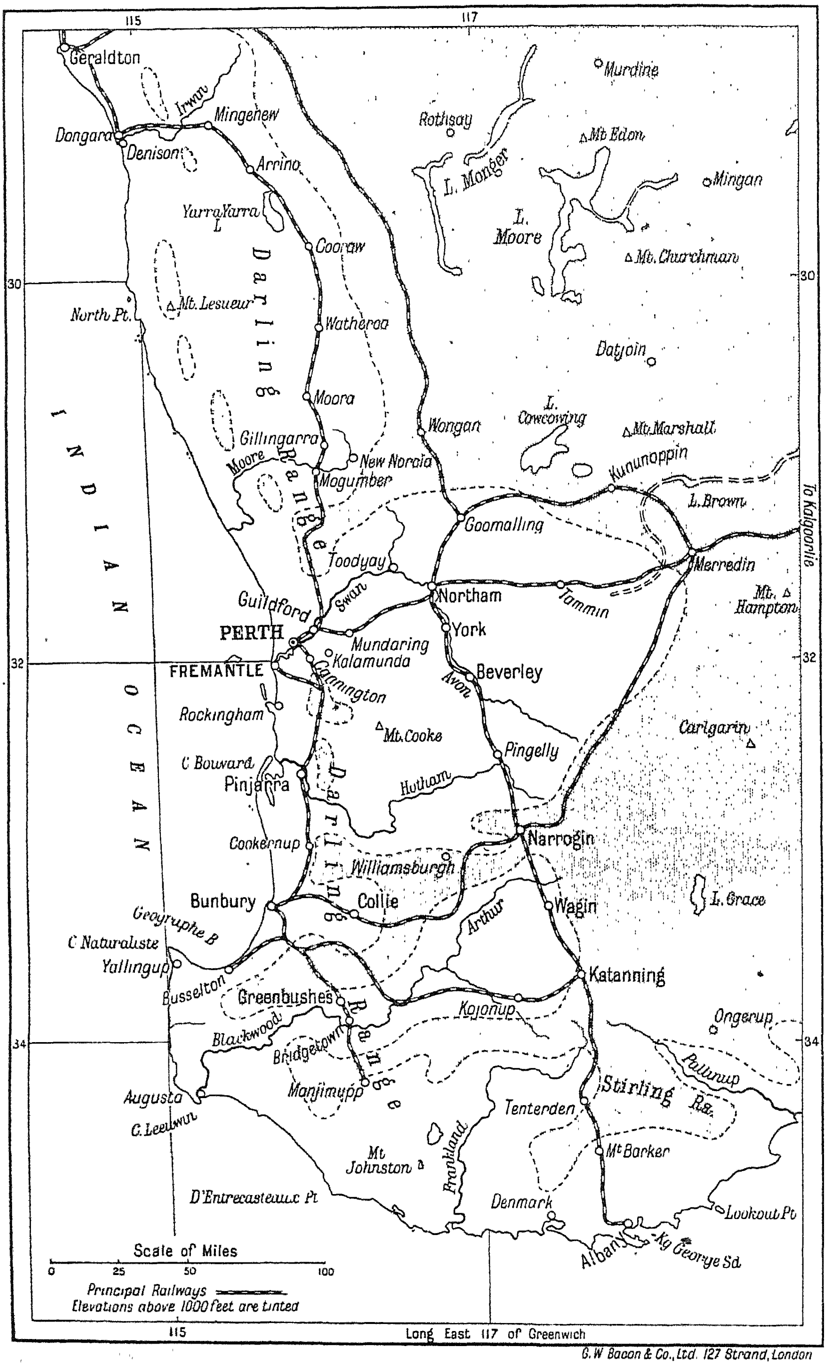

Fig. 2.—Part of Western Australia, showing places visited by Members.

examples were shown on the screen. The doubling and the weight of stars, the movements of the stellar system and its probable shape were among other branches of the subject dealt with.

August 2, at the Literary Institute, Mr. H. Balfour on 'Primitive Methods of Making Fire, and their Survival for Ceremonial Purposes.' The first part of the lecture described the various methods whereby fire is obtained by friction of wood among primitive peoples in various parts of the world, and touched upon their possible origin and geographical dispersal. The second part was devoted to the consideration of the *ceremonial* retention of such primitive and obsolete methods by peoples of more advanced culture, among whom the earlier processes have, for ordinary domestic purposes, been superseded by improved appliances, such as the flint and steel or the lucifer match. The production of 'pure-fire' for use in religious ritual, 'need-fire' for averting epidemics and other calamities, and 'new-fire' as a means of promoting the welfare of crops, &c., afford very numerous and widely dispersed instances of the persistence in ceremonial fire-making of otherwise obsolete methods, and this aspect of the subject formed the main theme of the lecture, which was illustrated throughout with lantern-slides.

August 3, at the Museum, Professor A. D. Waller, F.R.S., on 'The Electrical Action of the Human Heart.' He gave a popular history of the electro-cardiogram, describing how it occurred to him in 1887 to use the limbs as electrodes leading off on opposite sides of the electrical equator of the heart from his right hand and left foot to a Lippmann electrometer, and watching the mercury column pulsate with his heart-beat; extending these investigations by means of Einthoven's string galvanometer he devised a simple formula for calculating the axial angle of the heart which is of physiological importance.

A lecture was also delivered in the Town Hall, Kalgoorlie, on July 31, by Mr. C. A. Buckmaster (lately an Assistant Secretary of the Board of Education) on 'Mining Education in England.' The lecturer gave an account of the efforts that have been made in England to provide instruction in relation to metalliferous mining for day and for evening students. Special reference was made to the founding and progress of the Royal School of Mines, of the School of Metalliferous Mining (Cornwall), and of the characteristics of these schools. Attention was also drawn to the value the English experiments would possess in the development of technical instruction in mining in Australia.

Various other lectures and speeches, of an unofficial character so far as concerned the Association, were delivered by Members, here as elsewhere, throughout the Meeting.

On the evening of July 29 the first graduation ceremony held by the University of Western Australia took place in the ballroom at Government House, His Excellency the Governor presiding. The Meeting was addressed by Mr. Cecil Andrews, Pro-Chancellor, and honorary degrees were conferred on the following members of the Overseas Party:—Prof. Gunnar Andersson, Prof. W. Bateson,* Dr. F. W. Dyson, Dr. A. C. Haddon, Prof. W. A. Herdman,* Sir H. Reichel, Prof. A. D. Waller, Prof. J. Walther.*

(* *In absentiâ.*)

Sir Winthrop Hackett, K.C.M.G., first Chancellor of the University and senior member of the Legislative Council, was similarly honoured *in absentiâ*, and a number of other degrees were also conferred. Dr. A. C. Haddon addressed the Meeting on behalf of the Association.

Field-work in Western Australia.—The principal object of the visit to Western Australia, however, was to carry out work in the field, mainly in the directions of botany, geology, zoology, and agricultural investigation. A number of official excursions had been arranged to this end, and among the localities and places visited by parties of the visitors were the Irwin country, the Darling Range (Kalamunda, Lesmurdie, Cannington, &c.); Mogumber, New Norcia (where Members were received at the Benedictine Monastery), and Gillingarra; Albany and its neighbourhood; Mount Barker, the Stirling Range, and Northam; Busselton and the Yallingup and Margaret River caves; Mundaring Weir; Kalgoorlie; and the Big Brook timber mills in the jarrah and karri forests, and Bridgetown. Informal visits were also made to points in the Darling Range and elsewhere in the neighbourhood of Perth.

Of scarcely less interest to zoologists and anthropologists were the discussions which resulted from visits to the collections at the Museum (under the direction of Messrs. Woolnough and Alexander), and to those at the University made by Professor W. J. Dakin from the Abrolhos Islands (the subject of a communication to Section D at Sydney). Throughout the visit to Western Australia, although no formal sectional meetings were held, the public lectures were well attended, and the conferences with local men of science dealt largely with questions of local research, and may confidently be expected to result in the advancement of Science.

The great majority of the Advance Party joined the Orient R.M.S. *Orvieto* at Fremantle, and sailed for Adelaide on August 4.

Adelaide, August 8-12.

Arrival at Adelaide: Railway Passes.—Apart from some individual Members who had arrived at earlier dates, the first party to arrive at Adelaide was that on board the Aberdeen s.s. *Euripides*, which berthed at the Outer Harbour on August 7—the day previous to that on which she was originally expected. The large party (some 140) on the R.M.S. *Orvieto* followed on the morning of August 8. Both steamers were met by some of the principal officers for the Meeting, and Members before leaving the vessels were supplied with railway passes, which, by the combined action and generosity of the Railway Commissioners in all the States, enabled the whole of the Overseas Party to travel without charge over Government railways throughout the Commonwealth, the passes being valid from August 4 to September 18, and including sleeping berths.

Information Lists: Conveyance from Stations, &c.—In the case of each of the parties landing from the steamers, compartments were reserved on one of the special trains running, in connection with the steamers, from the Outer Harbour to Adelaide. Each Member had

been supplied with an Information List containing particulars arranged under the following headings:—

Member's No.	Member's Name	No. of Conveyance from Adelaide Station	Train from Adelaide, August 12			Adelaide Address
			No. of Train	No. of Coach	No. of Compartment	

On the arrival of each party at Adelaide Station, cabs and motor-cars, each bearing a distinguishing number, were in waiting, and Members, being able to identify their conveyances from the numbers in the Information List (and with the assistance of local officers who were in attendance), were expeditiously conveyed to the addresses where accommodation had been arranged for them. Their baggage (excepting hand-baggage) was dealt with, here and elsewhere, independently. Contracts had been made with a firm of carriers in each centre to collect and distribute baggage. The special luggage-labels bore the Members' distinguishing numbers in large figures, in order that the carriers might be able readily to sort the baggage.

The same method of distributing both Members and their baggage on arrival at each centre was relied upon throughout.

The Reception Room (Elder Hall) and Association Offices at Adelaide were established in the University.

The Meeting and the War.—It was known, not only in Australia but also to the Members arriving at this date, that the British Empire had become involved in war. The majority of Members of the Council present in Adelaide therefore immediately met (on the afternoon of August 8) in order to assure the Australian authorities of their acquiescence, on behalf of the Overseas Party, in any modification of the programme which might be found desirable in these unhappy circumstances. Professors Orme Masson, T. W. Edgeworth David, and E. C. Stirling were present, and, as official representatives of the Federal Council and the Local Executives, expressed appreciation of the thoughtfulness which prompted this assurance, but felt strongly that the scientific and other business of the Meeting should proceed, even if it were necessary to modify some of the social functions. A telegram received by the President while this discussion was in progress, from His Excellency the Governor-General, Sir R. Munro-Ferguson, supported these views:—

> 'I heartily welcome you and the Members of the British Association to Australia. Wish your arrival could have taken place in a less anxious time, but trust that, in spite of the grave pre-occupation of the moment, your visit may be a happy one and fruitful in good results.'

It may be stated here that this wish, so far as concerned the visiting party, was amply fulfilled. Modifications consequent upon the international situation were practically negligible, so far as concerned the Australian programme, although, as will be seen later, the plans for the homeward journeys of many of the Members had to be changed.

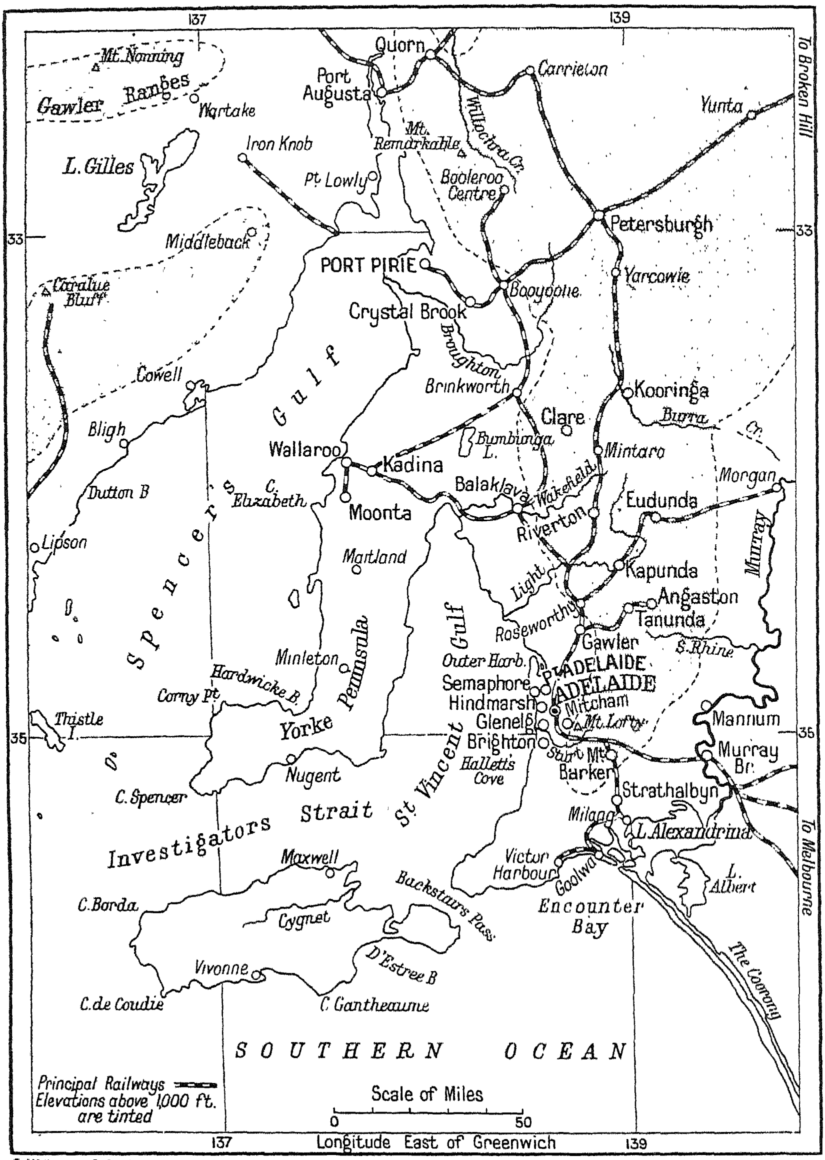

FIG. 3.—Part of South Australia, showing places visited by Members.

Australian public men and private citizens did not allow 'the grave pre-occupation of the moment' to interfere in any perceptible measure with their interest in the proceedings of the Meeting, and the hospitality and community of sentiment which were everywhere encountered by the visitors were possibly enhanced, certainly undiminished, by the stress of these external circumstances.

The position of some of the foreign guests among the Overseas Party gave rise to anxious consideration, but it may be recorded here that all were enabled to participate in the Meeting.

Saturday, August 8.—In the afternoon (in addition to the meeting mentioned above) a graduation ceremony was held in the Town Hall, when honorary degrees were conferred upon the following Overseas Members:—Prof. T. Hudson Beare, Prof. E. W. Brown, Prof. A. P. Coleman, Mr. A. D. Hall, Prof. G. W. O. Howe, Prof. H. Jungersen, Dr. C. F. Juritz, Sir Oliver Lodge, Sir Charles P. Lucas, Prof. F. von Luschan, Prof. A. Penck, Prof. Elliot Smith, Prof. W. J. Sollas. A degree was also conferred upon Prof. T. W. Edgeworth David (Sydney). Prof. E. C. Stirling welcomed the visitors, and Sir Oliver Lodge, in replying, read the telegram from the Governor-General quoted above.

Motor-cars, generously provided by the Local Executive and private residents, conveyed many Members (on this and the following days) for drives through the city, into the hills (Mount Lofty, &c.), and to other points of interest in the locality. In the afternoon a party of geologists and chemists left for a visit to Port Pirie and Broken Hill, which occupied most of them till the following Tuesday.

At 8.30 P.M. a Reception was held in the Town Hall by the Government of South Australia. Speeches of welcome were delivered by His Excellency the State Governor, Sir H. Galway, K.C.M.G., and by the Hon. A. H. Peake, State Premier; and Sir Oliver Lodge, F.R.S., President of the Association, replied.

Sunday, August 9.—No official engagements were arranged. A special afternoon service took place in St. Peter's Cathedral.

The Adelaide Municipal Tramways Trust despatched special cars, and, as already indicated, private motor-cars were also available for the purpose of informal excursions in the neighbourhood of the city.

At 8.15 P.M. Professor E. C. K. Gonner delivered a Citizens' Lecture in the Town Hall on 'Saving and Spending,' under the auspices of the South Australian branch of the Workers' Educational Association. The lecture dealt with the processes involved in saving and spending, and their ultimate effects upon the community, with particular reference to the ways in which and the objects for which people save. The chair was taken by Mr. T. Ryan, President of the Branch, and the lecture was followed by speeches from Sir Oliver Lodge and Professor W. Bateson.

Monday, August 10, was devoted to excursions. It may be stated in regard to excursions generally, not only from Adelaide but elsewhere, that they were arranged primarily with an eye to the scientific interests [2]

[2] The excursions are briefly summarised in the following diary: a discussion of the special scientific interests of some of them will be found in later pages.

of the visiting Members, and did not afford opportunity for any large proportion of the local Members to take part in them. Recognising this generous attitude on the part of the local organisers and Members, the General Secretaries of the Association addressed a circular letter to Members of the Overseas Party in Adelaide, inviting them to take advantage to the utmost of the official excursion arrangements.

A general all-day excursion took place to Angaston and district. Luncheon was provided by Mr. Charles Angas in the Agricultural Hall at Angaston. Mr. Glynn, Commonwealth Minister of External Affairs, proposed the toast of the visitors, and Sir Oliver Lodge replied. Sir H. R. Reichel proposed the health of Mr. and Mrs. Angas. Motor-cars were provided by residents to convey Members on short drives in the neighbourhood. A limited party visited the vineyards and cellars of Messrs. Seppelt, at Seppeltsfield, and lunched there. On the return journey the Château Tanunda Company's wine-cellars at Tanunda were inspected, and tea was provided by the Company. A botanical excursion by motor to the hills near Adelaide was conducted by Professor T. G. B. Osborn; and Professor E. C. Stirling led an anthropological excursion to Milang, Lake Alexandrina, where a party of aborigines was seen. Mr. W. Howchin conducted a geological excursion, lasting over August 10 and 11, by motor to the Sturt River, Hallett's Cove, Inman Valley, and Sellicks' Hill, the party spending the night at Victor Harbour.

In the evening of August 10 at 8.30, Sir Oliver J. Lodge, F.R.S., President, delivered a discourse on 'The Ether of Space.' His Excellency the Governor, Sir H. Galway, K.C.M.G., presided. The lecturer described the properties of the ether of space as the omnipresent connecting medium, and maintained its complete reality, in spite of its intangible and generally insensible character. He discussed the relation between ether and matter, and urged that the experimental elusiveness of the ether was a natural consequence of its uniformity and of the universality of its functions. A vote of thanks to the lecturer was proposed by Professor E. C. Stirling, C.M.G., F.R.S., and seconded by Professor T. W. Edgeworth David, C.M.G., F.R.S.

Tuesday, August 11.—Further excursions took place: to Roseworthy Agricultural College, under Mr. A. J. Perkins, Director of Agriculture; and to Mannum (a botanical excursion by motor, under Professor T. G. B. Osborn), while opportunities were again provided to visit the hills by motor, luncheon and tea being kindly furnished at a number of private houses in the Mount Lofty district.

A luncheon to some sixty visiting Members was given by the Commonwealth Club. Sir J. Downer was in the chair, and speeches were delivered by him and by Professor W. Bateson, Sir E. Schäfer, Sir C. P. Lucas, and Professor J. Perry.

An Evening Discourse was given at 8 P.M. in the Town Hall by Professor W. J. Sollas, F.R.S., on "Ancient Hunters," Sir Oliver Lodge presiding. The lecturer emphasised the results of recent research in dispelling exaggerated notions as to the antiquity of known remains of the human race, and discussed the correlation of the

palæolithic races of Europe with existing hunting tribes—*e.g.*, Australian, Bushman, Eskimo—and the early development and rapid progress of the human race in the arts. A vote of thanks was proposed by Dr. Verco, President of the Royal Society of South Australia, and seconded by Dr. A. C. Haddon, F.R.S.

A telegram of welcome to the Association from Mr. Cook, Prime Minister of the Commonwealth, was read from the chair: 'Heartiest of welcomes to the British Association for the Advancement of Science, and warm felicitations on its first meeting in Australia. We are greatly honoured in having as our guests so many distinguished torch-bearers of truth, and from so many lands. May the light you bring continue to shine through the mists which momentarily have settled upon the world.'

The Right Worshipful the Mayor of Adelaide, Mr. A. A. Simpson, held a Reception (in lieu of the Ball which had been arranged) in the Exhibition Building.

Wednesday, August 12.—Sectional Presidential Addresses were delivered in the Town Hall:—

At 10 A.M. Sir Charles P. Lucas, K.C.B., K.C.M.G. (Section E, Geography).

At 11.30 A.M. Mr. A. D. Hall, F.R.S. (Section M, Agriculture, Part I).

Railway Arrangements.—The Overseas Party, accompanied (as it was throughout) by a few official and other inter-State Members, left Adelaide in the afternoon by three special trains at 2.37, 3.30, and 6 P.M. Sleeping-berth accommodation was provided on this and all subsequent night-journeys for every Member, berths having been previously allocated by the organisers, and the Members informed of their places by means of the Information Lists. The scheme of these lists was broadly the same throughout: thus the Melbourne Information List, distributed in Adelaide, contained the following particulars:—

No.	Name	No. of Conveyance from Melbourne Station	Trains from Albury, August 19		Melbourne Address
			No. of Train	Coach and Compartment	

Melbourne, August 13-19.

Thursday, August 13.—The special trains arrived at Spencer Street Station, Melbourne, shortly before eight o'clock, nine o'clock, and noon respectively.

The business of the Meeting was carried on for the most part in the University of Melbourne, the Reception Room being established in the Wilson Hall, while the Sectional Meetings were held in lecture theatres or other rooms, as follows:—

Section

A—Natural Philosophy Department.

B—Chemistry Department.

C—Geology Department.

Section
D—Biology Department.
E—Physics Room, Teachers' College.
F—Main Hall, Teachers' College.
G—Engineering Department.
H—Anatomy Department.
I—Physiology Department.
K—Philosophy Room.
L—Art Room, Teachers' College.
M—Medical Theatre.

Luncheon and tea were served in the Union Building, where smoking and ladies' rooms, &c., were also provided. The Secretarium was established in the Grand Hotel, Spring Street.

Members were requested to attend at the Reception Room during the afternoon, to make final arrangements with regard to excursions. A representative of the Melbourne Excursions Committee, however, had attended in the Reception Room at Adelaide, and thus many Members had been able to make their applications in advance: the same principle was adopted throughout, a Sydney representative attending for this purpose at Melbourne, and a Brisbane representative at Sydney.

The Council met at 4 P.M., and the General Committee at 4.30 P.M., in the Biological Department.

In the afternoon a number of Members were entertained by an exhibition of boomerang-throwing given by Dr. Harvey Sutton and others.

In the evening a Reception was given at Federal Government House by Their Excellencies the Governor-General and Lady Helen Munro-Ferguson.

Friday, August 14.—In the morning the Sections met, and in five of them (Mathematics and Physics, Chemistry, Zoology, Economics, Physiology) presidential addresses were delivered.

In the afternoon a graduation ceremony was held in the Melba Hall of the University at 2.15, when honorary degrees were conferred upon the following members:—Professor C. G. Abbot, Professor H. E. Armstrong, Professor W. Bateson, Professor W. M. Davis, Dr. F. W Dyson, Sir Thomas H. Holland, Professor Luigi Luiggi, Professor W. J. Pope, Professor A. W. Porter, Sir Ernest Rutherford, Sir E. A. Schäfer, Professor J. Walther.

Later in the afternoon a Civic Reception was given in the Town Hall by the Lord Mayor (Mr. Hennessy) and citizens of Melbourne.

At 8.30 P.M., in the Auditorium, the Presidency of the Association was assumed by Professor William Bateson, F.R.S., in succession to Sir Oliver Lodge, F.R.S., who introduced the new President. Professor Bateson delivered the first part of his address, and a vote of thanks was proposed by His Excellency the Governor-General (Sir R. Munro-Ferguson) and seconded by His Excellency the Governor of Victoria (Sir Arthur Stanley).

Saturday, August 15, was devoted to excursions, visits being paid to Ballarat, Bendigo, Bacchus Marsh, Marysville, Emerald, Warburton,

National Park, the Macedon district, and Werribee. At Ballarat the party were the guests of the Mayor of the City, Mr. Brokenshire, and the Mayor of Ballarat East, Mr. Pittard. Some of the Members proceeded to Creswick to inspect the Government plantations and nursery, and were the guests of the Minister of Forests at luncheon, the Premier, Sir A. Peacock, presiding in the unavoidable absence of the Minister. At Bendigo the Mayor, Mr. Andrew, and others received the party.

The party visiting Bacchus Marsh alighted at Ballarat Plateau and descended to the Werribee River, where the glaciated floor, conglo-

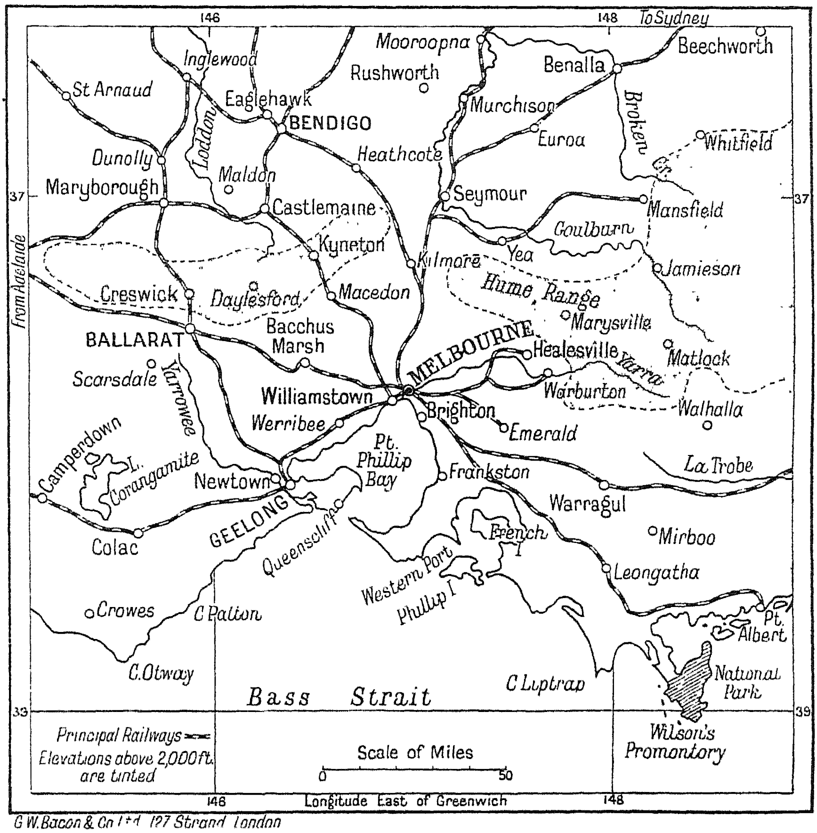

Fig. 4.—Part of Victoria, showing places visited by Members.

merate, &c., were examined; the gorge was then ascended and the Ordovician dykes, glacials, &c., were inspected. The party then drove to Bacchus Marsh.

The Marysville excursion lasted from Saturday to Monday, and included a journey by motor through Lilydale, up the Valley of the Yarra, to Healesville and the adjacent elevated district, with its forest of giant eucalyptus; on the road thence to Marysville the Blacks' Spur was crossed at a height of about 1,800 feet.

The Emerald excursion included a visit to Ferntree Gully, and took the visitors over the interesting narrow-gauge railway through the hilly bush country by Belgrave and Paradise. At Warburton and Cement Creek also pine forests and tree-fern gullies were seen, and the visitors were entertained by Mr. Jas. Cuming, who afforded them opportunity to inspect the saw-milling and allied industries in operation near Warburton.

The National Park excursion lasted from Friday night till Monday, the varied flora of the park and the granite and other geological features of Wilson's Promontory and the adjacent mainland being inspected. It had been intended to reach the promontory by a Government steamer, but as this was required for other purposes the journey was made overland, and involved riding over a considerable distance.

The excursion to the Macedon district introduced visitors to an area of great geological interest, on account especially of the newer basalt plains of Keilor and the trachytic and other volcanic features in the vicinity of Macedon.

At Werribee (an excursion primarily of agricultural interest) the Central Research Farm was inspected, and the Members were addressed by Mr. Hutchinson, Minister of Agriculture, and Dr. S. S. Cameron, Director of Agriculture.

At 8 P.M. Dr. W. Rosenhain, F.R.S., delivered a Citizens' Lecture in the Town Hall on 'The Making of a Big Gun,' the Lord Mayor of Melbourne presiding.

Sunday, August 16:—No official arrangements were made for this day. A considerable number of Members were away on extended excursions. Special services took place,. or special sermons were delivered, in several of the principal churches in Melbourne.

Monday, August 17.—Some sectional work occupied the forenoon.

At 4 P.M. Professor E. B. Poulton, F.R.S., delivered in the Auditorium a Discourse on 'Mimicry.' The lecturer dealt with cryptic resemblance, or that form of mimicry the purpose of which is concealment, with the sematic or advertising uses of colour, and with other forms of imitation, illustrating his remarks by examples from animal, fish, insect, and plant life, and then went on to consider those forms of true mimicry where a harmless insect is protected by the resemblance it has acquired to some other form having distasteful qualities. The President presided, and a vote of thanks was proposed by Professor W. Baldwin Spencer, C.M.G., F.R.S., and seconded by Professor A. Dendy, F.R.S.

In the evening a Reception was given by the Government of Victoria in the Public Library, National Gallery, and Museums. The Premier and Lady Peacock, the President and Mrs. Bateson, the President of the Legislative Council (Mr. J. M. Davies), Dr. and Mrs. Leeper, and the Speaker of the Legislative Assembly (Sir F. Madden) received guests in the Stawell Gallery.

Tuesday, August 18.—The Sections continued their work this morning, and some carried their sessions on into the afternoon.

In the afternoon a Reception was given by members of local scientific societies in the Botanical Gardens.

The Lord Mayor of Melbourne (Mr. Hennessy), President of the Overseas Club, and other members of its Council, waited upon Professor Bateson at Federal Government House in order to present him as President of the Association with an address of welcome from the Club.

At 8.30 P.M., in the Auditorium, Dr. F. W. Dyson, F.R.S., Astronomer Royal, delivered a Discourse on 'Greenwich Observatory.' He discussed the history of the Observatory, its work, and the labours of some of his predecessors in office; a number of astronomical photographs were shown and explained. A vote of thanks was proposed by Professor Orme Masson, F.R.S., and seconded by Mr. P. Baracchi, Government Astronomer.

At 8 P.M., in the Town Hall, Professor H. B. Dixon, F.R.S., delivered a Citizens' Lecture on 'Explosions,' His Excellency the State Governor presiding.

Wednesday, *August* 19.—Sectional work was continued in the morning, but the time available was limited by the hour fixed for the departure of the party from Melbourne for Sydney.

Railway Arrangements.—The departure took place at 2.15 P.M. A very heavy train of the finest rolling stock, including observation and dining cars and drawn by two locomotives, conveyed the party as far as Albury, where a break of gauge occurs between the railways of Victoria (5 ft. 3 in.) and of New South Wales (4 ft. 8½ in.). The Members were the guests of the Victorian Railway Commissioners at afternoon tea and dinner on this train.

At Albury Members were transferred to three special sleeping-car trains.

Changes in Homeward Steamship Sailings.—It had become known by this time that the three ships by which the majority of the Members had travelled out (the *Orvieto*, *Ascanius*, and *Euripides*), and by which many intended to return, had been requisitioned, among others, for Government purposes (conveyance of troops, &c.) in connection with the war. Mr. Atlee Hunt, of the Commonwealth Department of External Affairs, and the representatives of the shipping companies concerned, gave the executive officers of the Association every help in ensuring that definite information in this matter should be furnished to Overseas Members as soon as available. The official arrangements for the visit of a party of Members to New Zealand had been cancelled (as narrated elsewhere). It therefore became necessary to the organisation that a further inquiry should be made of Members as to any change in their plans regarding their stay in and departure from Australia. This inquiry was made by means of a printed form distributed in the train between Melbourne and Albury.

Overseas Members' Contribution to Australian Patriotic Funds.—It had also been decided, at a meeting of the General Officers on August 15, that Members in the Overseas Party should be given an opportunity of subscribing to one of the Patriotic Funds then being raised in Australia, and in this connection also advantage was taken of the gathering together in one train of practically the whole party to

make this proposal known and begin the collection. The total sum ultimately collected, and forwarded to His Excellency the Governor-General after the close of the Meeting, amounted to 614*l.* 8*s.*[3]

Sydney, August 20-26.

Thursday, August 20.—The special trains arrived at Sydney between 9 and 10 A.M. In the morning and afternoon Members visited the Reception Room. As at other centres, all the business of the Association, except evening lectures, was carried on at the University. The Great Hall served as the Reception Room. The Sections made use of lecture theatres or other halls as follows:—

Section
- A—Physics Department.
- B—Chemistry Department.
- C—Geology Department.
- D—Zoology Department.
- E—Pathology Theatre.
- F—Surgical Theatre.
- G—Engineering Building.
- H—Anatomy Theatre.
- I—Physiology Lecture Room.
- K—Latin Lecture Room.
- L—Mathematics Lecture Room.
- M—Veterinary Science Lecture Room.

For certain joint and other meetings the Union Hall was used.

[3] The following letter of acknowledgment was received from His Excellency the Governor-General:—

9th September, 1914.

DEAR PROFESSOR BATESON,—

I have to-day received your letter dated the 6th instant, and accompanying which is a cheque for 611*l.* 6*s.*,† representing the combined contributions by the Members of the Overseas Visiting Party of the British Association to the Patriotic Fund now being raised in Australia.

I need hardly assure you that this most kind and generous contribution by the visiting Members of the Association will be most deeply and warmly appreciated by all sections of the people of Australia, not so much because it represents a very substantial addition to the Fund referred to, but rather on account of the community of spirit and of sympathy it indicates.

In view of the fact that each State in the Commonwealth has a distinct Patriotic Fund of its own, it has been decided, after careful consideration, that the fairest and most satisfactory method for the distribution of the sum that has been forwarded will be to divide it equally amongst the various States, a decision which, it is hoped, will meet with the approval of those who have so liberally contributed to the relief of Australian fellow-countrymen. I am accordingly despatching 100*l.* to the Executive Authority administering the Patriotic Fund in each capital, together with a copy of your letter and of the list of names of subscribers.

I am,
Yours very sincerely,
(Signed) R. M. FERGUSON.

The President,
British Association for the Advancement of Science.

[† The balance was forwarded later.]

Smoking and refreshment rooms were established in the University Union Building, and refreshments were also served in the Refectory. The Secretarium was established in the Australia Hotel, Castlereagh Street.

On *August* 20, at 8.30 P.M., in the Town Hall, the President, Professor W. Bateson, F.R.S., delivered the second part of his Address. His Excellency the Governor of New South Wales, Sir G. Strickland, presided, and a vote of thanks was proposed by Sir William Cullen and seconded by Sir E. A. Schäfer, ex-President.

Friday, August 21.—The Sections began their sessions in Sydney, Presidential Addresses being delivered in those of Geology, Engineering, Anthropology, Botany, and Education.

At 1 P.M. a luncheon was given at the Town Hall to the Overseas Members and others by the State Government. The toast of 'The British Association' was proposed by the Premier, Mr. Holman. Professor Bateson replied, and Sir Oliver Lodge proposed the toast of 'The Government and Ministry of New South Wales.'

Later in the afternoon His Excellency the Governor of New South Wales, Sir Gerald Strickland, G.C.M.G., gave a Garden Party at 'Cranbrook,' Rose Bay.

At 8.30 P.M., in the Town Hall, Professor G. Elliot Smith, F.R.S., delivered a Discourse on 'Primitive Man.' The President presided. The lecturer discussed in some detail the remains of primitive man of the Pleistocene and later periods, referring especially to the supposed Pleistocene skull the discovery of which in the Darling Downs had been described earlier in the day in the Anthropological Section. He discussed and illustrated the evolution of mankind, and the links connecting the brain of man with those of lower animals. A vote of thanks was proposed by Sir Everard im Thurn, K.C.M.G., and seconded by Sir T. Anderson Stuart.

Saturday, August 22, was devoted to excursions.

A party leaving Sydney on Friday night, and returning on Sunday evening, visited the Federal Territory, Canberra (the site of the Federal capital), and the Burrinjuck Dam. Other places and districts of interest which were visited by Overseas Members were—Coonamble and Walgett (for the Western plains, the wheat belt, and the pastoral industry); the Jenolan Caves and the fine limestone ravine scenery of the Blue Mountains at Wentworth Falls, Katoomba and Blackheath; Narramine (where arborglyphs were inspected); the Murrumbidgee irrigation area at Yanco; the Hawkesbury Agricultural College; the Hawkesbury River and Newport districts; the National Park and Port Hacking; Bulli and the Cataract Dam; and the electrolytic works at Port Kembla. A geological excursion visited West Maitland and the lower Hunter district and coal-field.

Further references to the excursions from Sydney will be found among the notes on scientific work which follow this narrative.

At 8 P.M., in the Town Hall, Professor Benjamin Moore, F.R.S., delivered a Citizens' Lecture on 'Brown Earth and Bright Sunshine,' the Lord Mayor presiding. Here, as elsewhere, the arrangements were

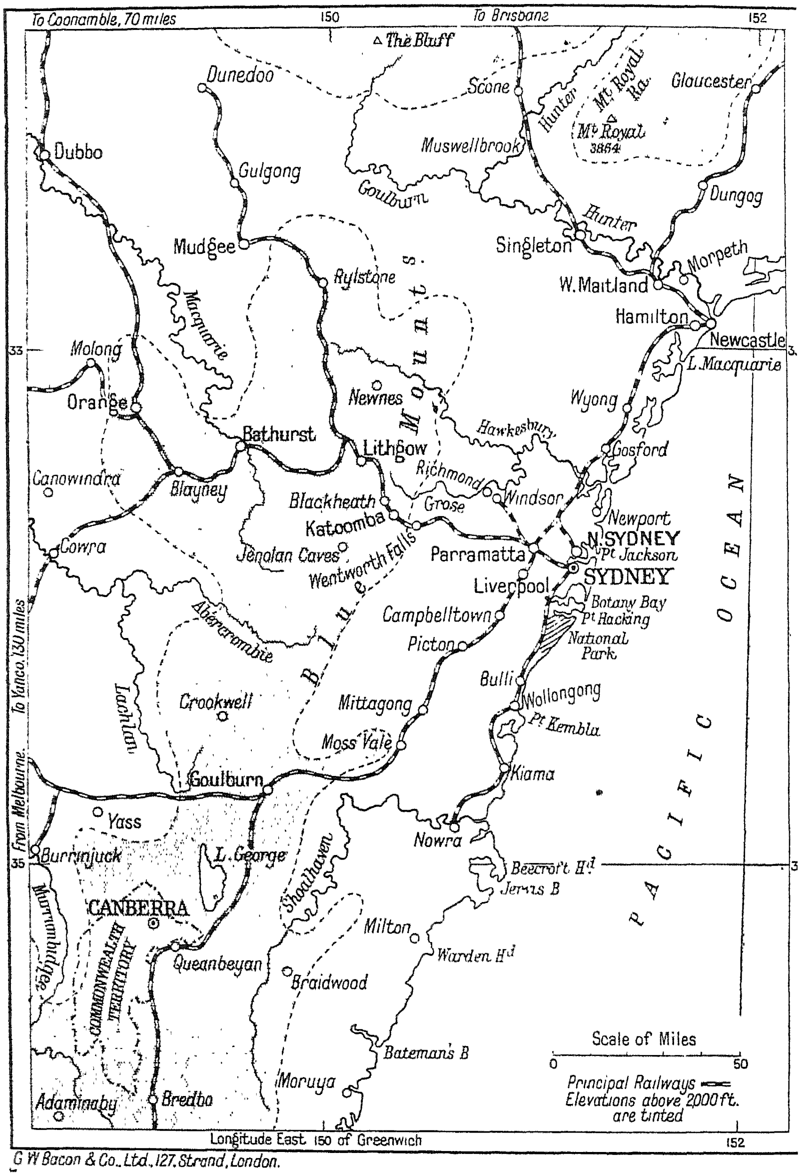

FIG. 5.—Part of New South Wales, showing places visited by Members.

undertaken by the Workers' Educational Association. The lecturer dealt with the process of evolution from inorganic bodies. He showed that under the influence of bright sunshine the brown colouring matter (iron oxides) of the earth was capable of stirring up energy and forming organic compounds which then served as a substratum for the evolution of the simplest living organisms.

Sunday, August 23.—No official engagements were arranged. Some of the longer excursions were proceeding. In the cathedral and other places of worship special sermons were delivered.

Monday, August 24.—Excursions were continued. Some of the Sections held Meetings in the afternoon. At 8 P.M. in the Lyceum Theatre, Pitt Street, Prof. Sir Ernest Rutherford, F.R.S., delivered a Discourse on 'Atoms and Electrons.' Sir Oliver J. Lodge, F.R.S., ex-President, presided. The lecturer summarised the history of doctrines concerning the unit of matter from ancient times to the present, and then led up to some of the alternative forms of the modern electrical theory of the constitution of the atom, giving reasons for his own preference for the view of a central positively charged nucleus surrounded by a number of negative electrons revolving in astronomical orbits round it, the number being closely connected with the appropriate atomic weight or position in Mendeléef's series. Professor Pollock proposed a vote of thanks to the lecturer. A ball was given at the Town Hall by invitation of the Right Hon. the Lord Mayor (Alderman Richards).

Tuesday, August 25.—All the Sections met in the morning, and some continued their sessions in the afternoon. The Committee of Recommendations met in the Senate Room at 2.30 P.M. An excursion in Sydney Harbour was given in the afternoon by invitation of the Commissioners of the Harbour Trust.

At 8 P.M. in the Town Hall Professor H. H. Turner, F.R.S., delivered a Citizens' Lecture on 'Comets.' The chair was taken by Mr. Meredith Atkinson.

A Conversazione offered by the Senate at the University was cancelled owing to the death, on the previous day, of the Chancellor of the University, Sir H. N. MacLaurin. Honorary degrees were to have been conferred on the following Members:—Prof. W. Bateson, Prof. F. O. Bower, Prof. E. G. Coker, Prof. A. Dendy, Prof. E. C. K. Gonner, Prof. W. A. Herdman, Sir Everard im Thurn, Prof. B. Moore, Prof. J. Perry, Prof. E. B. Poulton, Prof. H. H. Turner. These degrees were conferred subsequently *in absentiâ*.

Some of the members of the Overseas Party (to the number of 26), who, owing to the war and the cancellation of the sailing of the R.M.S. *Orvieto*, found it incumbent upon them to hasten their departure from Australia, left Sydney this evening by train in order to join the P. & O. R.M.S. *Malwa*, homeward bound, at Adelaide.

Some of those who left thus early (by this or other routes) had originally intended to proceed to Brisbane; on the other hand, some who had intended to visit New Zealand, where the official arrangements had been abandoned, now desired to be included in the Brisbane party.

These eleventh-hour alterations created a difficult situation for the Executive at Brisbane, but it was ably and generously dealt with. Members now desiring to be included in the Brisbane party were allowed, so far as possible, to take the places of those who no longer desired inclusion, the party (of 182 members) being kept at or about the total number originally arranged for. Members of the Brisbane Executive attended at Sydney and worked with the general organisers in rearranging the party: the allocation of railway accommodation for the journey north from Sydney had to be recast, and the Brisbane Executive had in the short time available to make many new dispositions in regard to guests and hosts, but they were able to distribute complete Information Lists on the special trains in ample time before Brisbane was reached. Of that section of the party which did not proceed to Brisbane some stayed in Sydney or made other independent arrangements; a few, under the informal leadership of Sir E. Rutherford, F.R.S., visited New Zealand.

Wednesday, August 26.—Some of the Sections met in the morning. The first special sleeping-car train left for Brisbane at 12.40 and the second at 1.50 P.M. Dinner was served at Singleton, where the President and other official Members (travelling on the first train) were received by the Mayor.

Brisbane, August 27—*September* 1.

Thursday, August 27.—The trains reached Wallangarra, at the frontier between New South Wales and Queensland, about 7.25 and 8.5 A.M. respectively. Here breakfast was provided, the Members, at this meal and luncheon at Toowoomba, being the guests of the Queensland Government. Tickets for these meals had been distributed on the trains during the previous day's journey, together with ribbon-badges which constituted free passes over the tramways in Brisbane. A break of gauge occurs at Wallangarra, the Queensland Government lines being of 3 ft. 6 in. gauge. Members continued their journey from this point in two special trains, which reached Brisbane at 5.33 and 6.15 P.M. respectively. The party was accompanied from Wallangarra to Toowoomba by the General Traffic Manager at Toowoomba, and thenceforward by the Deputy Commissioner for Railways. The Deputy Mayor of Toowoomba (Mr. T. A. Price) welcomed official Members as the first train passed. By the courtesy of the railway officials, the second train made two short stops, enabling passengers to alight while passing through the fine scenery of the ranges near Toowoomba.

Friday, August 28.—The Reception Room was established in the former Government House, now occupied by the University.

At 10 A.M. in the Albert Hall Mr. A. D. Hall, F.R.S., delivered the second part of his Presidential Address to Section M (Agriculture), dealing in particular with tropical agriculture, and at 11.30 A.M. in the same place Professor E. W. Brown, F.R.S., Vice-President of Section A (Mathematics and Physics), delivered an address in the Department of Cosmical Physics.

In the afternoon some of the official and other leading Members were

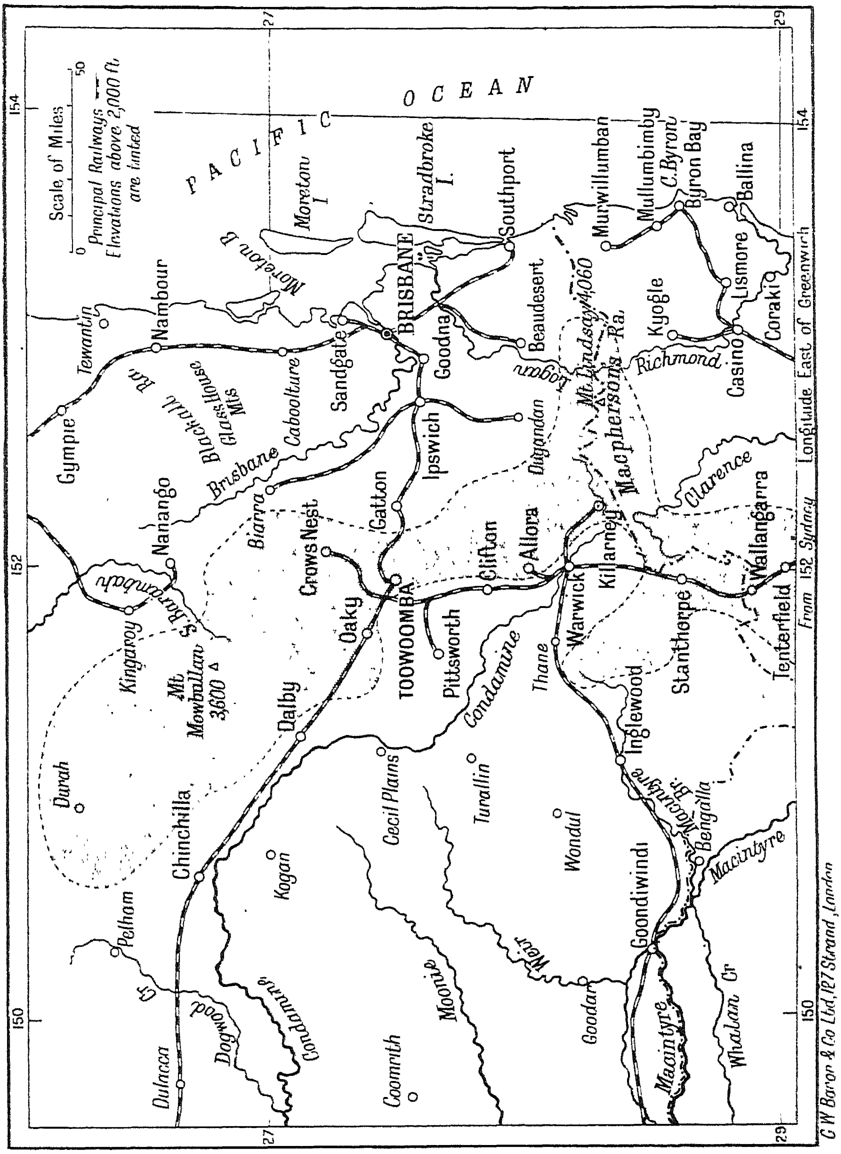

Fig. 6.—Part of Queensland, showing places visited by Members.

entertained to luncheon by the Senate of the University. Mr. R. H. Roe, M.A., Vice-Chancellor, was in the chair, and the President, Professor Bateson, expressed the thanks of the Members. Opportunity was given for short excursions through Brisbane by tram-car. The Worshipful the Mayor held a Civic Reception in Bowen Park.

A small party left Brisbane for Dulacca (returning on the following Sunday evening) to inspect the experiments being conducted there by Dr. Jean White for the extermination of the prickly pear.

In the evening, at 8.30, discourses were given in the Centennial Hall by Professor H. E. Armstrong, F.R.S., on 'The Materials of Life,' and in the Albert Hall by Professor G. W. O. Howe on 'Wireless Telegraphy.' At the first the President was in the chair. Professor Armstrong discussed the part played by chemistry in the investigation of his subject, and showed how simpler compounds of carbon, hydrogen, oxygen and nitrogen were built up into the more complicated substances found in the plant; he then traced the breaking up of these in digestion and the further formation from simpler substances of the more complex materials of the animal's body. Professor B. D. Steele proposed a vote of thanks.

Sir Oliver Lodge, F.R.S., presided at the discourse by Professor Howe, who, after explaining the principles of the subject, traced their practical application in the development of the various systems of wireless telegraphy. A number of lantern slides were shown, illustrating the construction of modern high-power stations. Sir A. Cowley proposed, and Professor Luigi Luiggi seconded, a vote of thanks to the lecturer.

Saturday, August 29, was devoted to excursions. Opportunity was afforded for visits to the Ipswich railway workshops and the vicinity of the town; to Nambour and the Blackall Range (an excursion arranged for and taken advantage of by a large party, amounting to some two-thirds of the visiting Members); to the Glass House Mountains, to visit which a small party left the special train to Nambour and proceeded on foot to the summit of Mount Ngun Ngun and to the bottom of the cliffs on Mount Crookneck, rejoining the special train on its return; through the Cleveland district, south of the Brisbane River, and to Mount Coot-tha, a view-point within the metropolitan area. At Nambour the Moreton Central Sugar Mill was inspected, and at luncheon the visitors were welcomed by the Mayor of Nambour and the Maroochy Shire Council. The Range and the Maroochy river were subsequently visited, and tea was served on the return to Nambour. A longer excursion undertaken by some of the Members was that to Gympie Goldfield, the party being the guests of the Corporation of Gympie, and returning to Brisbane on Sunday morning.

Sunday, August 30.—As elsewhere, no official arrangements were made for the Sunday. At night, however, a few members left for Mount Morgan Gold and Copper Mine (420 miles from Brisbane), an excursion which lasted until Thursday morning, September 3.

Monday, August 31.—In the morning an excursion was made by steamer down the Brisbane River to the meat-works situated thereon.

In the afternoon the Hon. the Premier of Queensland gave a garden party in the University grounds. In the evening, at 8 P.M., Dr. A. C. Haddon delivered a Citizens' Lecture, in the Exhibition Hall, on 'Decorative Art in Papua,' the Mayor of Brisbane presiding.

At 8.30 P.M., in the Centennial Hall, Sir Edward Schäfer, F.R.S., ex-President, delivered a concluding discourse on 'Australia and the British Association.' In the course of his lecture, which was of a valedictory character, he drew a comparison between the inhospitable conditions encountered by James Cook when he led the first scientific expedition on board the *Endeavour* from Great Britain to the shores of Australia, and the conditions of high civilisation and the warm welcome which the visiting Members of the British Association found. He briefly traced the history of the Association, and showed how the advancement of science, which is its object, had rendered the visit to Australia possible. He dealt with the need for encouraging scientific research, with especial regard to the possibilities of the future in Australia. The President took the chair, and the Lieutenant-Governor of Queensland (Sir Arthur Morgan) and Sir Oliver Lodge, F.R.S., proposed and seconded a vote of thanks to the lecturer. Both the President and Sir Oliver Lodge took occasion to express the deep gratitude felt by every visiting Member for the magnificent reception accorded to the party throughout Australia, and for the unremitting labour by which the many residents in Australia who had been concerned in the organisation of the Meeting had ensured its success; in this connection the speakers paid an especial tribute to the work of the General Organising Secretary, Dr. A. C. D. Rivett, and Mrs. Rivett.

Letter to the Australian Press.—On the conclusion of the Meeting the following letter was addressed to the Press in Perth, Adelaide, Melbourne, Sydney, and Brisbane:—

To the Editor of the ....

Sir,—The meetings of the British Association for the Advancement of Science in Australia, at the five capital cities of Perth, Adelaide, Melbourne, Sydney, and Brisbane, have been brought to a close, and we desire, before leaving the country, to make public expression of our gratitude to the people of the Commonwealth, on behalf, as we feel confident that we may, of the whole party of some three hundred members who have made the journey from overseas.

From the moment when the invitation to hold our meetings here was extended to the general committee of the Association at the Sheffield meeting in 1910, by Sir George Reid, on behalf of the Commonwealth Government and Professor Orme Masson, Chairman of the Federal Council, we have met with nothing but goodwill and earnest collaboration from all the authorities which have been concerned in the arrangements made for our visit and meetings. The Commonwealth Government placed a large sum at the disposal of our Council as a contribution towards the expenses incurred by upwards of 150 of our members in making the voyage. The Governments of the

various States have contributed freely towards the expenses involved by the very elaborate and complete arrangements made locally for the meetings, and have, moreover, provided each overseas member with a pass over their railway systems covering a period of six weeks, while their Railways Commissioners have made admirable provision for the transport of our large party between the different centres of meeting, and in connection with excursions during our stay at these centres. Moreover, in dealing with many intricate details of organisation, both before and during the meeting, we have been always able to rely on the cordial advice and help of representatives of the Government both in this country and at home. The establishment of a central office for the purposes of organisation in Australia, in the Commonwealth Government buildings in Melbourne, under the conduct of Dr. A. C. D. Rivett, has proved to be the wisest method of ensuring constant and thorough collaboration with our own permanent office in London during the past eighteen months, and between the many authorities in Australia, and has guaranteed that uniformity of organising work in the various centres which has contributed so largely to the successful working of the meeting as a whole. The Universities in the five centres have placed their buildings unreservedly at the services of the Association, and municipal and other authorities owning buildings have been no less generous.

To all those of our colleagues and helpers in Australia, who as chairmen or members of the Federal Council, general committees, executive committees, and hospitality committees, as local secretaries and treasurers, as organisers of excursions, information stewards, assistants in the reception rooms, or in other capacities, official and unofficial, have freely taken upon themselves labours, often arduous and prolonged, in connection with the meeting, we venture to offer this general expression of our heartfelt thanks; we cannot hope to do justice in every case to individual effort. The hospitality, both private and public, which has been extended to visitors throughout the journey has exceeded any possible expectation.

Finally, we desire to acknowledge very gratefully the extraordinary public interest which has been aroused in the proceedings of the meeting, and, moreover, has been maintained in face of the lamentable events which have occurred in Europe during our stay here. A practical illustration of that interest is afforded by the fact that a much greater number of members has been enrolled for this Australian meeting than for any previous meeting in the history of the Association. The importance of a large local membership to the interests and advancement of science, which is the sole object of the Association, has already been explained, and is clearly very well understood, in Australia. We need not labour the point, but may conclude by assuring the people of Australia that the announcement of a grand total for the meetings, in all centres, of more than 4,700 members[4] forms, in our view, a fitting

[4] The exact number of Overseas Members and local Members and Associates was 4,930. The local enrolment was made up as follows—Adelaide, 599; Melbourne, 2,017; Sydney, 1,780; Brisbane, 234.

climax to a meeting of unparalleled interest to the visitors, and, we venture to hope, of value to the country in which it has been held.-

We are, Sir, Yours, &c.,

W. BATESON, President,

JOHN PERRY, General Treasurer,

W. A. HERDMAN, } General Secretaries,
H. H. TURNER, }

O. J. R. HOWARTH, Assistant Secretary.

British Association for the Advancement of Science, Sept. 3.

Homeward Voyage.—After the conclusion of the Brisbane session the party became further divided. Of nearly 100 members who did not immediately return south about forty waited in Brisbane for the Burns Philp s.s. *Montoro*, which sailed on September 3 for Northern Queensland, Java, and Singapore. Others made various individual arrangements. A party of 88, however, was conveyed south by a special train leaving Brisbane on September 1 at 8.30 A.M., and reaching Wallangarra in the evening, where members were transferred to a special sleeping-car train, which reached Sydney shortly after noon on September 2. Beyond this point no further special transport arrangements were required. Sixty-three of the Members sailed from Australia on the P. & O. R.M.S. *Morea*, which left Sydney on September 5, Melbourne on September 8, and Adelaide on September 10, but these members made individual arrangements as to joining the ship, and some did so at each of the three ports named.

Visit to Tasmania.—A party of twenty-one Members, under the leadership of Professor T. Thomson Flynn, visited Tasmania, leaving Melbourne by the s.s. *Loongana* on September 5, and arriving at Launceston on September 6. At Launceston the Museum and the Cataract Gorge were visited, and on September 7 the party proceeded to Hobart by rail. On September 8 receptions were held at the Town Hall, the Museum, and the University, and an official luncheon at Government House was given by His Excellency the Governor of Tasmania, Sir W. Ellison-Macartney, and Lady Ellison-Macartney. In the evening Dr. G. T. Moody lectured on ‘ Some Commercial Aspects of Education.’ On September 9 Mount Wellington was visited, and on September 10 several other excursions took place in the neighbourhood of Hobart. On September 11 the party proceeded to Maria Island on the east coast, where geological, zoological, and botanical collections were made and dredging was carried out in the neighbouring sea. On September 13 the kitchen middens at Little Swan Port were explored, and the party returned to Hobart, the principal part of the programme having been completed. The zoologists, however, remained, and Professor Dendy gave an address to the Royal Society of Tasmania on ‘ Progressive Evolution.’ Dr. W. M. Tattersall gave a public lecture on ‘ The Depths of the Sea.’ On September 16 the zoological party proceeded to the Great Lake and carried out collecting in the lake and its neighbourhood, returning to Hobart on September 22.

Table of Distances.—The following approximate figures may be of interest:—

	Statute Miles.
England [London] to:—	
Adelaide *via* Suez (all sea)	12,740
Do., overland to Mediterranean	11,700
Adelaide *via* South Africa	13,895
England [Liverpool] to:—	
Sydney *via* Vancouver	14,529
Fremantle-Adelaide (sea)	1,356
Adelaide-Melbourne (rail)	483
Melbourne-Sydney (rail)	582½
Sydney-Brisbane (rail)	725

The weather was fine practically throughout the meeting.

Notes on Scientific Work in Australia.

Throughout the sessions in the various centres, in addition to the official meetings and excursions, special meetings, discussions and expeditions, informal as well as formal, were arranged by local men of science for particular groups in the Overseas Party. On such occasions (among which may be included the visits paid to University laboratories, museums and other institutions by many of the party) problems for investigation were pointed out and plans for future research were suggested, of value to hosts and guests alike, and it is not improbable that some of these informal conferences may have as great a direct effect upon the advancement of Science in Australia as the more public Meetings of the Association. As the Report volume does not elsewhere offer any occasion to indicate the work done in these directions, a summary may be given here, with reference to the Sections whose interests were specially concerned. The list of Research Committees appointed on the recommendation of the Committee of Recommendations meeting at Sydney will show that in many departments of Science, under several Sections, important suggestions for research were given effect.

In Section A, owing to the unfortunate absence through ill-health of the President, Professor Trouton, his address was read by Professor A. W. Porter. The attendance at the Sectional Meetings was good at both Melbourne and Sydney; and specially large audiences gathered to hear the discussions on 'Atoms and Molecules' (jointly with Section B: opened by Sir E. Rutherford, followed by Professors Pope, Armstrong, Kerr Grant, Hicks, and others, with Sir O. Lodge in the chair), on 'Antarctic Meteorology' (opened by Dr. Simpson, followed by Captain Davis, Mr. Gold, and others), and on 'Wireless Telegraphy' (opened by Sir O. Lodge). Sir E. Rutherford's paper was also of special interest. A paper by Mr. Baracchi, Government Astronomer of Victoria, on the proposed site for a Solar Observatory on Mount Stromlo was of particular interest to the Astronomers, and the Prime Minister of the Commonwealth (Mr. Cook) received a deputation[5] of

[5] The Astronomer Royal, Professors Turner, Eddington, Duffield, and Nicholson, Mr. C. G. Abbot, of Washington, Sir Oliver Lodge, introduced by Professor Masson. Mr. Deakin and Mr. Hunt, Government Meteorologist, were also present.

astronomers and physicists on this project, and accorded them a favourable hearing. In Sydney the local branch of the British Astronomical Association requested, through the President, Dr. Roseby, a visit from the Astronomers; and the Astronomer Royal, Professors E. W. Brown, Eddington, Nicholson and Turner and Mr. C. G. Abbot attended and addressed the meeting. The Sydney branch of the Mathematical Association also invited some visiting mathematicians to address them; Professors Perry and Turner responded to Professor Carslaw's invitation. The different State observatories (Perth, Adelaide, Melbourne and Sydney) and Mr. Tebbutt's private observatory at Windsor, N.S.W., were all visited by several astronomers, and as a result of friendly discussion of problems and difficulties, invited by the directors of the observatories, several memoranda were drawn up by the visitors.

The geologists of the party in Western Australia, under the local guidance of Professor Woolnough, visited the Irwin River to examine the Permo-Carboniferous glacial beds, marine beds and coal measures, the Darling Ranges to see the crush-conglomerates of Pre-Cambrian age, the Stirling Ranges with their highly contorted quartzites of unknown age, and finally the goldfields of Kalgoorlie and Coolgardie. At the time of the Adelaide meeting a party of geologists and chemists visited Port Pirie and Broken Hill for the purpose of seeing the occurrence of the ores and the methods of working and smelting. Another party at the same time visited the Sturt River to see the Cambrian glacial beds, and explored the Permo-Carboniferous glacial beds and the archæocyathine limestones of Hallett's Cove, and finally the granitic rocks in the neighbourhood of Victor Harbour. From Melbourne the geologists went to Macedon to examine the alkaline igneous rocks and to Bacchus Marsh for the Permo-Carboniferous glacial tillites lying upon striated surfaces of older rocks.

From Sydney there were excursions of both geological and biological interest to the Blue Mountains, which afforded the geologists an opportunity of studying the leading features of the geological structure of New South Wales and the remarkable elevation which this, in common with many other parts of the Continent, experienced in late Tertiary or post-Tertiary times. An examination was also made of the Jenolan Caves, which are typical examples of stalactitic caves in limestone of Silurian age, one of the interesting features of which was the remains of an aboriginal skeleton embedded in the stalagmitic floor. The excursion to West Maitland and Newcastle gave an opportunity of examining the productive coal measures of the State.

At Brisbane two of the most notable excursions arranged for geologists were those to the Glass House Mountains, a series of trachytic volcanic necks rising abruptly from the plain, and to Ipswich to examine the Trias-Jura coal measures and associated volcanic rocks.

Some of the most noteworthy points that impressed the geologists from Europe were the remarkable extent on the Australian Continent of Permo-Carboniferous glaciation, the evidence of comparatively recent extensive elevation, the well-preserved plains of erosion at different geological horizons, and the evidences of glaciation as early as the Cambrian epoch.

At each centre visited the zoologists of the party were in close touch with the professor of the subject at the University and other local workers, and many of the excursions, both those in the official programme and others of a more informal character, were arranged so as to show the visiting specialists as much as possible of the Australian fauna.

At Perth, in addition to the definitely zoological excursions to the Yallingup caves and to the Mundaring Weir, Professor Dakin arranged to take a few of the zoologists to visit points of interest on the Darling Range, where *Peripatus* and other important organisms were found.

From Adelaide parties of zoologists made observing and collecting trips to Lake Alexandrina, Victor Harbour on the coast, the Mount Lofty Range, and elsewhere, at all of which objects of interest were seen and much material collected which may lead to research.

At Melbourne the local naturalists arranged several short trips in the neighbourhood to study the birds and the land fauna generally; while at Sydney the excursions were naturally rather of a marine biological character. Professor Haswell and Dr. S. J. Johnstone organised a collecting party in Port Jackson in order to explore from a steam launch the wonderfully rich invertebrate fauna exposed at low tide in various parts of the harbour.

From Sydney, again, the various excursions to the Blue Mountains and the Jenolan Caves gave zoologists the opportunity of collecting such rare and interesting forms as *Peripatus* and land Planarians and of seeing many of the characteristic birds and insects of the country; and the same may be said of some of the excursions from Brisbane.

At the Museums and University laboratories of Perth, Adelaide, Melbourne, Sydney, and Brisbane informal discussions and conferences took place with the Museum Curators and other local naturalists, which led to the formation of Research Committees or to plans for future work on Australian problems.

In connection with the marine fauna, the question of more fully exploring the Australian fisheries was under consideration at several centres, and it seems probable that a more thorough investigation of the coastal waters and their contained plankton, by modern oceanographical methods, will be undertaken at an early date. Another outcome of informal conversations was the resolution brought before the Committee of Recommendations for adoption by the Council of the Association welcoming the project to convert a portion of Kangaroo Island in South Australia into a Government Reserve for the protection of the fast-disappearing native land fauna.

The facilities given to members of Section E (Geography) to study on the spot various types of land-forms in Australia were especially valued by those whose interests lie mainly in physical geography. Others had the opportunity of observing the influence of geographical factors, notably temperature and rainfall, upon the more important forms of economic activity in the country. The visit to Western Australia and the excursions to Yanco, Bendigo, and Gympie were of especial interest. Some members took advantage of their stay in the different capitals to make themselves acquainted with the literature relating to the discovery and early settlement of the Continent.

Probably the communication to the Anthropological Section which will be regarded as of greatest scientific importance was the exposition by Professors David and Wilson, at Sydney, of the highly mineralised skull of an Australian man, probably of Pleistocene date. This skull, which shows certain features in common with that of the Sussex Piltdown skull, was found some thirty years ago on the Darling Downs, and Professor David was fortunately able, on an excursion subsequent to the Meeting, to find the original discoverer of the skull and obtain exact particulars as to the locality and mode of occurrence.

Opportunities were given wherever possible to allow the anthropologists to see for themselves the aborigines and their craftsmanship. Thus, from Adelaide, under the guidance of Professor Stirling, a party went to Milang on Lake Alexandrina to inspect a number of men, women, and children from the Mission Station, including some full-blooded aborigines. These gave displays of dancing, boomerang-throwing, hut-building, and basket-making, and some of the party collected information in regard to cat's-cradle games and native genealogies.

The anthropological collections in the Museums at Melbourne, Sydney, Adelaide, Brisbane, and Perth were naturally of great interest, and under the guidance of the curators and other local anthropologists there were important discussions and critical examination of specimens by experts, which will doubtless lead to further research.

In the Melbourne Museum the magnificent collections of Australian stone implements, especially brought together for the occasion by Messrs. Kenyon and Mahony, as well as the ceremonial objects collected by Professor Spencer, were on exhibition during the meeting, and were the subject of careful examination and discussion. Much of the more productive scientific work of the anthropologists naturally consisted in informal conferences with the local workers, and it was hoped that as one of the results of such consultations it might be possible to obtain from the Federal Government the assistance which is necessary for the prosecution of further research in the fast-disappearing cultural anthropology of the tribes in the Northern Territory.

Field-work naturally played a large part in the botanical programme. At Perth an extended expedition to Albany, lasting for the greater part of a week, gave opportunities for studying the characteristic vegetation of the arid districts of Western Australia. From Adelaide there were three important excursions arranged specially for botanical work—one to study the *Salicornia* Scrub and the mangrove swamps of the coastal region, one to the Mount Lofty Range to see the fern gullies and the scrub of the higher levels, and the third to Mannum.

The botanical excursions from Melbourne arranged by Professor Ewart included one to Emerald for the fern gullies, while a smaller party went on to visit Dr. MacArthur's station to inspect the methods of orchard planting. Another party was taken to Warburton to inspect a characteristic 'big-tree' region and study the ecology of the district.

From Sydney, in addition to the excursions to the Blue Mountains and to the Jenolan Caves district, of great interest to botanists as well as geologists, there were a number of smaller informal excursions under

the guidance of Professor Lawson to study the botany of the Port Jackson neighbourhood, including the National Park. Another important botanical party, under the direction of Mr. Maiden, visited the Bulli Pass and the Cataract Dam, passing through interesting country and a rich fern vegetation. Mr. Maiden also conducted the botanists over the Sydney Botanic Gardens and gave a special exposition of the Herbarium.

Of special botanical interest was the excursion from Brisbane to Nambour and the Blackall Ranges, showing sugar-cane cultivation and many ferns, aerial orchids and other characteristic plants of the upland gullies.

Before the regular work of the Association began several members of the Agricultural Section took the opportunity of gaining some acquaintance with the special conditions of farming prevailing in Australia.

The chief questions that occupied the attention of the Section both in session and out of doors were dry farming, irrigation, and the breeding of cereals. In South Australia dry-farming methods were receiving a searching test because of the prevailing drought. Notwithstanding, the wheat after fallow showed little sign of flagging, and impressed everyone by its brilliant green colour. Visits were paid to the Roseworthy Experimental Farm in South Australia and the Werribee Farm in Victoria. At both places experiments were in progress to illustrate the effects of various cultivations and of taking a fodder crop before the wheat. This raises one of the most important problems in Australian wheat-growing, the maintenance of the fertility of the soil under continuous cropping. At present it is contended that the system of alternate wheat and fallow, still more so the rotation of wheat, stubble grazed by sheep, fallow, does not result in any diminution of the nitrogen content of the soil. Accurate data, however, are lacking, and as it is difficult to understand how the normal recuperative actions in the soil should be sufficient to maintain the stock of nitrogen it is desirable that this question, fundamental for the future of Australian farming, should be submitted to rigorous examination. Dry-farming problems were discussed generally by the President, and in a valuable paper by Dr. Lyman Briggs, who summarised the extensive investigations on the water requirements of plants that have recently been carried out at various stations in the Great Plains of North America. Several of the points brought out—the comparatively low water requirement of the millets and sorghums and the great variation in the water requirements of various strains of lucerne—are likely to become of practical value. As regards irrigation, in addition to the discussion at Melbourne, the Members of the Section visited the small irrigation colonies on the lower Murray, the colonies at Bacchus Marsh and Werribee, near Melbourne, and the great Yanco settlement in New South Wales, where a meeting was also held and papers read. On the subject of cereal-breeding a fruitful discussion took place in Sydney. Mr. Beaven brought out the importance of what he terms the migration factor, not only in determining the yield of a given variety, but also as a means of picking out the high-yielding varieties among the great

number of seedlings with which the breeder always has to deal. It was pointed out that the value of several of Farrer's wheats must be due to their high migration factor. Farrer's work was discussed at some length, and the President of the Association pointed out how he worked on Mendelian lines in pre-Mendelian days, in that he bred his stocks from individuals picked out in the second and succeeding generations of cross-breds.

Dairying is an industry of great importance in Australia, and received considerable attention in the Section by means of discussions on milk yields and milk records, and on the current types of milking machines, without which dairying can hardly be carried on in Australia. Some of the members of the Section interested in this side of the work spent a large proportion of their available time amongst the dairying in the coastal districts of New South Wales and Queensland, and were greatly impressed by the labour-saving devices that have there been adopted. The problems of wool character and wool inheritance were raised both in the meetings and in the field, and though it will be long before so complex a character is brought under control, the question did receive some elucidation which may serve as a basis for future work.

The members of the Section owe a particular debt of thanks to the Agricultural Departments of the various States; in every case special arrangements were made for them, individually and collectively, so that each man had the opportunity of seeing the local work in which he was most interested.

Resolution by the Council.

At the Meeting of the Council of the Association held in London on November 6, 1914, it was resolved:—

'That the Council of the British Association for the Advancement of Science, at its first Meeting in London since the return of Members from Australia, desires to place on record its high appreciation of the generous reception given to the Members of the Overseas Party throughout the Commonwealth by representatives of the Governments of the Commonwealth and the States, and by other authorities and Australian citizens generally, on the occasion of the Meeting of the Association in Australia in 1914. The Council hereby expresses its grateful thanks for the hospitality, privileges and concessions extended so freely to visiting Members, and also for the willing and valuable collaboration of all those who undertook so successfully the work of organisation in Australia in connection with the Meeting.'

VISIT OF MEMBERS OF THE BRITISH ASSOCIATION TO THE MEETING OF L'ASSOCIATION FRANÇAISE POUR L'AVANCEMENT DES SCIENCES, LE HAVRE, 1914.

It was reported to the Council in November 1912 that a letter had been received from Dr. A. Loir, Director of the Bureau d'Hygiène, of Havre, and Local Secretary for the Meeting of L'Association Française pour l'Avancement des Sciences in Havre in 1914, intimating that that Association and the municipality of Havre desired to invite as guests leading Members of the British Association who might not be attending the Meeting in Australia, and that all Members not attending that Meeting would be welcomed at the Meeting of the French Association; also proposing that the Conference of Delegates should meet in Havre. Information had also been received from Dr. Loir that a Local Committee, including some of the principal British residents in Havre, had been formed for the reception of Members of the British Association if the above invitation were accepted. The Council resolved that the invitation be cordially accepted, in general terms, and that details of the arrangements be left in the hands of the President and General Officers, with the assistance of the following Committee: Dr. J. G. Garson, Dr. A. Vernon Harcourt, and Dr. P. Chalmers Mitchell. The Committee was empowered to add to its number.

It was decided in 1913, after discussion by the Corresponding Societies Committee, the Conference of Delegates at the Birmingham Meeting, the General Committee and the Council, that the Conference of Delegates should meet at Havre in 1914.

Report to the Council of the British Association of the Committee for the Havre Meeting of l'Association Française pour l'Avancement des Sciences.

The Committee have to report that the Havre Meeting of the Association Française pour l'Avancement des Sciences was held at Le Havre from the 27th to the 31st of July. Owing to the political situation it was found necessary to curtail the duration of the Meeting somewhat.

About forty Members and Associates of the British Association attended, and received a most cordial reception from their French *confrères;* several of them were also very hospitably entertained during the Meeting.

The final list of delegate officials from the British Association was as follows:—

Sir William Ramsay, K.C.B., F.R.S., Premier Delegate.
Sir Edward Brabrook, C.B.
Dr. J. G. Garson, Chairman of the Havre Committee.
Dr. F. A. Bather, D.Sc., F.R.S., Delegate of the Museums Association.
Professor A. H. Reginald Buller, Ph.D., University of Manitoba.

At the General Inaugural Meeting Sir William Ramsay gave an eloquent address in French, which was much appreciated by the audience.

Two meetings of the Conference of Delegates of Corresponding Societies were held; the first under the presidency of Sir Edward Brabrook, who in the absence

of Sir George Fordham, the Chairman of the Conference, read the address prepared by the latter. The ordinary business of the Conference was proceeded with. The second Conference was held under the presidency of M. Ray, and the organisation of French societies was discussed.

At the concluding general meeting Sir William Ramsay again addressed the meeting, and returned thanks on behalf of the Members of the British Association.

Several papers were contributed to the proceedings of Sections by Members of the British Association. An important discussion took place on 'Units of Measure,' and the question was asked whether the British Association would be willing to consider the matter and co-operate with the French Association.

No report of the Havre Meeting would be complete without allusion to the splendid work done in connection with it by Dr. Loir, the Local Secretary. To him the British Association visitors are very greatly indebted for his attention to their welfare and assistance during their stay at Havre.

The Committee also gratefully acknowledge the assistance and attention to the Members and Associates by H.B.M. Consul at Havre, Mr. C. V. Churchill.

The best thanks of the Association are due to Sir William Ramsay for his services as spokesman and the efficient manner in which he discharged the duties of premier delegate.

The Committee recommend that the thanks of the British Association should be formally transmitted to the French Association for this opportunity of friendly and fraternal co-operation between the scientific men of both countries, and to Professor Gautier, the President, M. Jules Siegfried, Deputy, the Maire of Havre, and Dr. Loir.

The above recommendations were carried out by order of the Council.

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. WILFRED MARK WEBB (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Sir H. G. FORDHAM, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Dr. A. C. HADDON, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Mr. A. L. LEWIS, Rev. T. R. R. STEBBING, *and the* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Committee recommends that the Museums Association should be made an Affiliated Society.

Sir George Fordham has promised to preside at the Conference of Delegates to be held at Havre at the invitation of the French Association for the Advancement of Science, and to give an Address on 'The History of the Endeavour to Co-ordinate the Work of Local Scientific Societies in Great Britain.'

The Committee recommends that the following subjects should be discussed at the Conference:—

'Local Natural History Societies and their Publications,' and 'The Question of the Compilation of an Index to the latter.' The first suggested by the Hertfordshire Natural History Society, to be introduced by Mr. John Hopkinson, and the second to be discussed by Mr. William Cole and Mr. Henry Whitehead on behalf of the Essex Field Club.

The Committee wishes to express its thanks to Mr. W. P. D. Stebbing for his services as Secretary, which he has had to relinquish owing to his absence abroad. The Committee asks to be reappointed, and applies for a grant of 25*l*.

Report of the Conference of Delegates of Corresponding Societies held at Havre on Tuesday, July 28, 1914, by invitation of the Association Française pour l'Avancement des Sciences.

Chairman.—Sir GEORGE FORDHAM, J.P., D.L.
Vice-Chairman.—Sir EDWARD BRABROOK, C.B., Dir.S.A.
Secretary.—WILFRED MARK WEBB, F.L.S., F.R.M.S.

In the absence of Sir George Fordham, Sir Edward Brabrook, the Vice-Chairman, presided, and the Corresponding Societies Committee was represented by Dr. J. G. Garson, Mr. John Hopkinson, and the Secretary, Mr. Wilfred Mark Webb. There were also present several Members of the British Association, other than delegates, as well as representatives of the French Association, including Dr. Loir, the Local Secretary.

Sir EDWARD BRABROOK thanked the French Association for the Advancement

of Science for having invited the Conference of Delegates to meet at Havre, and then proceeded to read the Chairman's Address on :—

The History of the Endeavour to Co-ordinate the Work of Local Scientific Societies in Great Britain.

More than thirty years have now elapsed from the period when an attempt was first made to group the local scientific societies of Great Britain and Ireland round the British Association, and to co-ordinate their work of local research and investigation on settled lines with that of the Association. It is possibly, therefore, an appropriate time for reviewing shortly, in the form of a presidential address, the results of this movement, and the success it has achieved. The initiative in this matter is due to Mr. John Hopkinson, then as now the moving spirit of the Hertfordshire Natural History Society, who, in a letter printed in 'Nature' on August 5, 1880, suggested a Conference of officials and annual delegates of local scientific societies during the meetings of the British Association. Such a meeting, small and informal, was held during the British Association week at Swansea, in August 1880, when twelve representatives were present from nine societies. Mr. Hopkinson was chairman of the meeting, and the following resolutions were adopted: That this Conference recommends that at future meetings of the British Association the delegates from the various scientific societies should meet with the view of promoting the best interests of the Association and of the several societies represented; that Mr. Hopkinson and Mr. H. George Fordham be a Committee to carry out the views expressed at this Conference, and report to the Conference of Delegates to be held at York in 1881, in accordance with the foregoing resolution.

In the result, four successive annual conferences were held: at York (1881), at Southampton (1882), at Southport (1883), and at Montreal (1884). They were arranged by a small Committee, and the expenses were met by contributions to a fund formed for the purpose by the delegates themselves. The interest in this movement was a growing one, and at the meeting in Montreal thirty-eight societies were represented by thirty-one delegates. During the five years of voluntary activity in this matter—to 1884—many circulars and notices were printed and issued to societies, and representations were made to the British Association itself in furtherance of the idea of co-operation upon which these preliminary Conferences were based. The minutes of these early Conferences and the discussions and reports they include, with some manuscript addition, as the copies now in my hands have been completed, make up twenty-two pages of octavo. In similar form a 'circular referring to subjects recommended for investigation by local scientific societies' issued by their Committee runs to eight pages. These thirty pages of print and manuscript contain a great many interesting discussions and many valuable suggestions, and give the summarised history of the movement in its early and unofficial stage.

It would not serve any useful purpose to analyse now these discussions of the suggestions made, and I do not propose to do so, but it seems well to draw attention to the effort made in the period 1880-1884, and to found upon it as the historical basis of what has been since developed.

The first stage of the official activity of the British Association in connection with local scientific work and organisation was naturally one of inquiry. An investigation was set on foot through a Committee of the Association appointed in 1882 and reporting in the following year on the lines of what had already been done unofficially, in order to obtain exact and complete knowledge of the number of scientific societies in the United Kingdom which could be properly classified as 'local,' their constitutions, the number of their members, and their objects, and in particular of the character, form, and frequency of their publications. It turned out to be an exceedingly tiresome one, but in the end the number of societies of a local character of sufficient consequence and stability to warrant their being recorded in the list prepared, was found to be about 190, as to which the information obtained was grouped in eight columns. The following paragraphs from the report of 1883 may be recalled: 'The local societies differ widely in character. Those which are established in large towns, and are not particularly well situated for carrying on systematic

local investigations, are often of high scientific rank, and their affairs are administered in a business-like manner by a regular staff. On the other hand, there are numerous smaller societies and field clubs, scattered over the country, which are excellently situated for conducting local investigations, and are in many cases doing valuable work, but of which so little is generally known that it has often been difficult to discover their official addresses. In some parts of the country the smaller societies either group themselves into what is practically a federation, or else affiliate themselves to some large society in their district, and the Committee think that if the local societies could more generally be induced to group themselves round what might be described as local sub-centres, it would not be difficult to devise methods of uniting the representatives of those sub-centres in the performance of interesting and important duties during the meetings of the British Association, with the final effect of establishing systematical local investigation throughout the country, and uniformity in the modes of publishing the results. The recommendations of the Committee will tend wholly in this direction, because, although they have considered many plans of fulfilling their instructions in a direct manner, no plan recommends itself to them as superior to this indirect method in its capacity for producing valuable and durable effects. It can hardly be doubted that numerous systematic investigations of a local character will continue to be carried on, and that their successful prosecution would result in important gains to science. Neither does it appear doubtful that the successful prosecution of such investigations by the smaller local societies would be greatly encouraged and facilitated by the general interest shown in their work by the more influential societies in their neighbourhood, by a watchful oversight, a readiness to discuss and publish results, and by the personal influence of their leading members. The Committee offer the recommendations they are about to make in the trust that they will serve to remind the more important local societies of the high and useful function they are able to perform by entering into friendly and helpful relations with the small and scattered societies of the respective districts, and by offering themselves as their scientific representatives wherever representations may be necessary.'

Subsequently, at a meeting of the General Committee of the Association held in London, on November 11, 1884 (by adjournment from Montreal), Rules proposed by the Council, upon the recommendations of the Committee of 1882-3 were finally adopted, and incorporated with the Rules of the Association. In accordance with the new rules a 'Corresponding Societies Committee,' consisting of (as then printed): Mr. F. Galton (Chairman), Professor Williamson, Captain D. Galton, Sir J. D. Hooker, Professor Flower, Professor Boyd Dawkins, Sir Rawson Rawson, Dr. Garson, Mr. J. Evans, Mr. J. Hopkinson, Mr. Meldola, Mr. Whitaker, Mr. Symons, and Mr. Fordham (Secretary), was appointed by the Council, and thereafter the whole of the work previously carried on, or attempted, by a voluntary body became a part of the official machinery of the Association, and the history of the official relations of the British Association and local scientific societies is found in successive annual reports of the Corresponding Societies Committee. These commence in 1885. In that year the Committee publish the first list of societies recommended by them for admission to the Roll of Corresponding Societies, 39 in number, a selection from amongst 52 applications. They also issue an Index List of Papers published during the previous year by these societies, arranged in groups according to the subjects referred to the various sections of the Association. The Index List in this form has been continued to the present time. In the Report for the following year (1886) are incorporated the proceedings and a report of the discussions which took place in the two Conferences of Delegates held during the meeting of the Association. The form of publication of this Annual Report and of the matter it contains has been since followed systematically. It would be impossible to summarise the whole series of these Reports within any reasonable compass, but some salient points may be noticed. As regards the number of societies officially associated with the British Association and the work it carries on the following figures may be given. In 1886 the societies which nominated delegates for the Conference numbered only 24; in the following year they were 32. At the end of the first decade, in 1896, they had

risen to 49. In 1906, when an additional class of corresponding societies had been created, they rose again to 72. In 1912 and 1913, when only those delegates who were present at a Conference were recorded, with the societies they represented, the figures are 52 and 55 respectively. This shows actually a progressive improvement throughout the whole period in the interest taken in the annual Conference and its work. In the same period the list of societies enrolled under the rules as Corresponding Societies is: in 1886, 36; in 1887, 38; in 1896, 66; in 1906, 80; in 1912 and 1913, 114 and 107. Thus the system set up in 1884, as since modified from time to time, seems to have obtained at least the success of an increasing numerical support for the idea of co-ordination of local scientific work through such a central body as the British Association. As regards the discussions at the Conferences and the various suggestions made, as well as the work done centrally in the endeavour to promote the co-ordinated activity of local societies, one is struck in reading through the annual Reports, as published from 1886 onwards, with their great value and interest. In every form, and with all possible suggestions, and a mass of valuable practical knowledge, those discussions have been carried on through the whole period. If the fruits of this consideration of the possibilities of the case had been at all in proportion to the labour and ability bestowed on the elucidation of the various subjects discussed, the advance in the utility to science of the local societies would be very great indeed. In 1904 the Chairman of the Conference, in reviewing the situation at that date, remarked that the results of the labours of the Conferences of the Delegates of Corresponding Societies 'have scarcely been commensurable with the expectations of those who instituted this body, or with the possibilities of the situation.' Now, ten years later, and speaking as one of those who took part in the creative stage of the present system, I am obliged to adopt the same opinion. It is certain that this system has been built up with care, and with a cordial desire to make it an efficient and helpful machine for the purposes contemplated so far as the officers of the British Association are concerned, and with the active and zealous assistance of the members of the Corresponding Societies Committee. It seems equally clear that, scattered throughout the membership of the local societies, are a considerable number of persons who have welcomed the efforts of the British Association in this direction, and have done their best to support them from the side of their societies. From the very beginning the weakness of the secretarial staff of the local societies has apparently been the difficulty in the way of success. It is hard to see how this difficulty can be got over. It is probable that here and there the local work of societies has been directed and stimulated, chiefly, no doubt, through the personal action of the delegates themselves.

Having regard to the value of many of the addresses and communications submitted to the annual Conferences, covering as they do the whole ground of the possible useful activity of local societies, it would seem almost worth considering whether the publication of a selection from these materials, grouped in some systematic form, could not be undertaken, so as to create a kind of code for the guidance of local societies in their activity.

One very valuable and important work carried on in connection with the grouping of Corresponding Societies is that of the compilation of an annual Index List of their scientific publications. I endorse the observations on this point which are to be found in the Report of the Corresponding Societies Committee for 1898: 'As the great majority of the societies, the main purpose of whose existence is local scientific investigation, are now on the list of Corresponding Societies, the Index of their most important papers approximates to completeness more and more each year as a record of local work.' Whatever else may happen, it is to be hoped that this annual List may continue to be prepared and published by the British Association.

I am far from thinking that the attention called to the relations of local societies to general scientific work during the long series of meetings held since 1882 has been useless or ineffective. I believe that in general much good has been done throughout the country, and I am sure there is much yet to do in this direction.

Dr. J. G. GARSON said that since the Conference had been officially recognised

he had been Chairman twice, and had held the office of Secretary. He endorsed Sir George Fordham's opinion with regard to secretaries. He thought that honorary work was badly done, and that the duties which secretaries of societies were called upon to carry out should be divided.

Mr. T. SHEPPARD (Yorkshire Naturalists' Union) proposed that the Conference send its best thanks to Sir George Fordham for his Address, which seemed a useful summary of the work of the Conference of Delegates.

On one point he wished to join issue with Dr. J. G. Garson, who had stated that honorary secretaries were usually bad secretaries. He knew of several, both paid and honorary, and his experience was usually not in favour of the paid official. He certainly found that an honorary secretary was enthusiastic, and had his heart and soul in the work, and worked well; while, as soon as he received a payment, his duties savoured of 'work,' and he lost interest in them. In the room were Mr. John Hopkinson, Mr. Lower Carter, Mr. Mark Webb, and others, whose work was certainly well known and was honorary.

Principal WITTON DAVIES (University College, Bangor) seconded the vote of thanks to Sir George Fordham, and asked whether it was possible for the committee of a museum to send a Delegate to the Conference of Corresponding Societies.

The subjects chosen for discussion were (1) 'Local Natural Histories and their Publications,' (2) 'The Question of the Compilation of an Index to the Latter.' The first was introduced by Mr. John Hopkinson, F.L.S., F.G.S., in the following paper entitled :—

Local Natural History Societies and their Publications.

The first essential in opening this discussion is perhaps to define its title so that the discussion may be neither too diffuse nor too restricted. I use the term 'Natural History' in its widest sense, as covering the whole of Nature on, beneath, and immediately above the surface of our earth, and therefore including geology and meteorology. The term 'local' restricts the inquiry to societies which are formed to investigate the Natural History of a particular area, such area in England usually being a county. When the county is large, a number of local societies, having their own independent organisation, may federate, forming one composite society such as the Yorkshire Naturalists' Union; and the several societies in a number of counties may also do so, for example, the South-Eastern Union of Scientific Societies.

I would therefore restrict the term 'Local Natural History Society' to those formed to investigate the Natural History of their locality, and no others I submit have a *raison d'être*. How then can this object best be accomplished? It would be impossible to form such a society without suitable material; men or women who study Nature. To bring them together the subscription should not be high, nor should there be any distinction of class. All naturalists, whatever their social position may be, should be welcomed and should be invited to bring before their society the subject of their special study. The next essential is an efficient secretary, who, besides having the general management of the society, should study its members, pick out the workers, and induce them to lay the results of their investigations before the society. At first the result may be desultory, but in course of time it will probably become more and more systematic. Thus one member may be induced not only to take meteorological observations but also to undertake the duty of meteorological recorder, collecting the observations of others, and in every county or nearly so there is a more or less numerous army of rainfall observers. Another may act as geological recorder, describing sections and photographing them, especially those of a temporary nature. Yet another may be an ornithologist, the camera here again being most useful, and he should be induced to give to the society an annual report on the birds which not only has he observed himself, but also including the observations of his correspondents. The most popular of the annual reports of the Recorders of the Hertfordshire Natural History Society is that of the Recorder of Birds, not only of our present Recorder, but each one for the last thirty-five years has been so. In botany an effort should be made to compile a flora of the county, phanerogamic and cryptogamic, if there is not one of somewhat recent compilation already in

existence, and if there be such a flora the duty of the Recorder would be to keep it up to date by his own observations and those of his correspondents. These are merely somewhat random examples of what a local society should do.

In but few localities, however, can such a society entirely rely upon active workers; there must be drones in the hive to supply the necessary funds by their subscriptions and to add to the numbers attending the meetings, and for them it will be necessary to provide popular lectures, which are now almost invariably illustrated by lantern-slides. In selecting such lectures regard should be had, so far as possible, to make them, while entertaining, conducive to serious study, so that there may be from time to time drafted from the army of drones recruits to swell the less numerous company of workers. The field meetings should be designed to investigate some special subject, for instance, the geology, botany, or some branch of the zoology of a district, under competent guidance, and while they should never be allowed to degenerate into picnics or mere pleasure parties, there is no reason why an occasional invitation of hospitality should be refused.

In a fairly large society the workers may be sufficiently numerous to form sections, each with its Recorder or Secretary, but it is only in very large ones that the sections should hold meetings to which the members generally are not admitted.

It is scarcely necessary to add that one of the objects of the Society should be the formation of a library of works on Natural History, especially of monographs or books which will enable species to be identified.

These brief remarks may suffice to promulgate a discussion on the general scope and management of a Local Natural History Society, and I therefore proceed to the second part of my title, the Publications of such societies. This I will consider, and I should like to be discussed, entirely from the point of view of a bibliographer. The question is, therefore : How can the publications be rendered most useful and most easily referred to and quoted by inquirers on the subjects of which they treat? The Editors of many, if not of most of the Local Natural History Societies of the British Isles, appear to strive to make this most difficult. Therefore I will briefly, and as I have not the time at my disposal to give my reasons in detail, it may appear dogmatically, lay down certain rules which I think should be strictly adhered to.

However much or however little is printed in a year, a volume with consecutive pagination, or it may be with two series of pages, one with Arabic numerals for the transactions or papers published, and the other with small Roman or italic numerals for the proceedings or accounts of the meetings, should eventually be produced, and this volume must not be so thin as to tempt two or more being bound in one, nor so thick as to require its being divided when bound. From 300 to 600 pages is perhaps the greatest latitude which should be allowed to a volume, but much will depend upon the thickness of the paper and the number of plates. It is immaterial whether two or more such volumes are produced in a year, or whether one volume takes several years to complete. This volume must have a title-page with the date of its completion and place of its publication, a table of contents at the beginning and an index at the end, and somewhere within it, that is, not only on the covers of the parts which it comprises, the date of publication of each part (month and year), with the numbers of the pages of which each part consists. It can then be ascertained at a glance in what part any paper appeared and the date of its publication. It is also advisable that after the table of contents there should be a list of the plates and of the text-figures, in each case showing their position in the volume.

When authors are supplied with separate copies of their papers the original pagination must be maintained, and in such copies, not only on their covers, must be printed the name of the publication, which may be abbreviated, and the volume, part, and date (month and year). As copies of papers may be cut out of a volume it is an excellent plan, now adopted in the 'Transactions of the Hertfordshire Natural History Society,' to print in small type, at the end of each paper, on the bottom of the page, the above particulars, which need not occupy more than one line and look best in italics. If that be done, what a bibliographer requires to know cannot be lost.

There are very few of these conditions, I may perhaps call them rules, which are generally observed in the publications of our smaller natural history societies.

Many such call their publications 'Annual Reports.' They may consist of not more than one or two sheets octavo (sixteen or thirty-two pages), each Report being separately paged. It may take ten or twenty to form a volume sufficiently thick to bind. As usually they have neither table of contents nor index, to ascertain whether a volume thus made up contains a paper on a certain subject nearly every page has to be turned over. There is as a rule no indication of the date of issue, and this is also usually the case with the separate parts of more pretentious publications, which may be called 'Journals,' 'Transactions,' or 'Proceedings,' at least after the covers have been removed, copies without the covers bound in being then absolutely useless to a bibliographer. Sometimes the index appears at the beginning, when one naturally looks for it at the end, such index occasionally being called 'Contents.' An index is, of course, alphabetical, and it is advisable that there should be only one, and not separate indexes of names, places, and subjects. Contents should comprise a list of the papers in the sequence in which they appear in the volume.

There is only one other point to which I desire to call attention, and that is the nature of the contents of the publications of a Local Natural History Society. The papers printed should be almost entirely those giving the results of original work, and, at least in a small society, for the sake of economy, as little space as possible should be given up to such things as rules and lists of members. It will usually suffice when a volume, as already defined, extends over several years, as is frequently the case with a small society, to give such things once only in each volume. Let me give you examples: one will suffice of the wrong way and two of the right way, and I may absolve myself from libel if I do not give the name of the society which transgresses. Its last publication is called 'Annual Report and Proceedings.' It is paged 1-48, not forming part of a volume. Except on the cover there is no date nor place of publication. Its chief contents are the Rules and Library Rules; Additions to Museum and Library; Financial Statement; Hon. Secretary's, Curator's, and Sectional Secretaries' Reports; and Lists of Members, past Presidents, and Associated Societies. The only additions to our knowledge of the Natural History of its locality are contained in a few pages of the Sectional Secretaries' Reports. The subscriptions of its members exceed 200*l*. per annum.

As examples of what I think should be published I will take the last part of the 'Transactions of the Hertfordshire Natural History Society,' the Society of which our present Chairman, Sir H. George Fordham, is now President, and the last part of the 'Journal of the Hastings and St. Leonards Natural History Society' issued under the main title of the 'Hastings and East Sussex Naturalist.' The Herts Society's 'Transactions' form Part 3 of Vol. XV., running from p. 105 to p. 192, and contain the following papers: Mimicry and Protective Resemblance (being the former President's Address); The Building of a Millepede's Nest (illustrated); Hertfordshire False-scorpions; Note on the Occurrence of *Palmodictyon viride* in Hertfordshire; The Crustacea of West Herts; The Weather of the year 1912 in Hertfordshire; On some Strata recently exposed in the Railway Cutting between Oxhey and Pinner; Notes on Birds observed in Hertfordshire during the year 1912; Hertfordshire Gentians; Botanical Observations in Hertfordshire during the years 1911 and 1912; Report on Land and Freshwater Mollusca observed in Hertfordshire in 1912; Recent Discoveries of Prehistoric Horse Remains in the Valley of the Stort (illustrated); Witches' Brooms on the Beech; The Weight-lifting Powers of Wasps; and Report on the Phenological Observations in Hertfordshire for the year 1912; with eight pages of Proceedings, xvii-xxiv. The papers were read between October 1912 and November 1913, and not one can be taken out without all which a bibliographer requires to know being on it, for at the bottom of the last page of each paper is the line *Trans. Hertfordshire Nat. Hist. Soc., Vol. XV., Part* 3, *May* 1914. The Society is only a small one, the subscriptions of its members scarcely amounting to 50*l*. per annum. It has published an excellent 'Flora of Hertfordshire.'

'The Hastings and East Sussex Naturalist' runs from p. 91 to p. 142 of Vol. II. The contents of the part are: Autobiographical Note by the Rev. E. N. Bloomfield (with portrait); Pioneer Work on the Fauna and Flora of the Hastings District; Annual Notes on the Local Fauna and Flora; Note on *Mycene Crocata*,

Fries; On the Recent Incursion of Waxwings; On the Arrival of Summer Migratory Birds in the Hastings District, 1893-1913; Rare and Unique Sussex Oligochets; A Cross-channel current at St. Leonards; and Wealden Floras: an admirable selection of local papers. There is, however, one slight omission, that is, a headline to each page, which should give the title, abbreviated when required, of each paper, and there is one very serious error: the date on the cover is correctly given as July 14, 1914, but the only date inside, on the first page, is April 18, 1914, so that were the cover removed that would be assumed to be the date of publication. There are important new records of species the correct date of the publication of which is essential, and this antedates them by three months.

I need only add that I shall be pleased to hear any comments on my views. Though you may think that I have been rather severe in my strictures on those who unduly augment the labours of a bibliographer, I hope you will admit that I have been so *à bon droit.*

The SECRETARY announced that no communication had been received from the Essex Field Club which had suggested the compilation of an index to the publications of Local Scientific Societies.[1]

Dr. F. A. BATHER (Museums Association) welcomed the practical suggestions of the author with regard to methods of publication. They were essentially the same as those made some twenty years ago by a British Association Committee on Zoological Bibliography and Publication, and distributed widely. One point, however, was not dealt with by the author, namely, the distribution of authors' copies in advance of publication; as to this, practical suggestions made by the Committee had been adopted by many societies, including eventually the British Association itself. The proposal to form a general index did not seem of a value commensurate with the labour. Each volume, of course, should be indexed, but for the rest the indexes and analytical bibliographies already being produced (*e.g.*, Zoological Record) should suffice. He would refer delegates to a report on the proper method of making up books recently issued by the Library Association and reviewed in *The Museums Journal.*

The CHAIRMAN said he agreed with the author, and would go still further by suggesting that in all cases a paper should begin on an odd page. He thought that the publication by local societies of their work would always be necessary, inasmuch as, for want of space, that work could not be adequately recorded by central or general societies. He proposed a vote of thanks to Mr. Hopkinson, which was unanimously accorded.

Mr. T. SHEPPARD spoke on the question of the publication of a general index, with some doubt as to its practicability. The work was so very enormous. With regard to Yorkshire alone, he had been busy with an index now for over three years, and when completed for the Yorkshire Geological Society it would probably cost well over 100*l.* Many societies had already prepared an index to their publications when they had covered a number of years. These, and the well-known general indexes, and bibliographies issued from time to time, should suffice.

Dr. F. A. BATHER regretted that, by the rules of the British Association, a premium had been placed on the issue of publications, and thought that aid would be valuable to and valued by the smaller societies, which often did good work but wisely refrained from needless publication. As for the collection of publications made by the British Association, it would be of more value to scientific workers if it could be transferred to the Library of the British Museum (Natural History), which experienced great difficulty in obtaining very many of these local reports.

Mr. JOHN HOPKINSON (Hertfordshire Natural History Society) could not admit Dr. Garson's contention that good work was not done gratuitously. He was familiar with the methods of management of many of our provincial societies, and could testify to the self-sacrificing devotion of their secretaries to the duties of their office; some of the best original work was also done by amateurs, especially in geological investigations. He could assure Dr. Bather that the British Association did not ignore the smaller non-publishing societies;

[1] A paper by Mr. William Cole, A.L.S., and Mr. Henry Whitehead, B.Sc., has since come to hand and is appended.

for in addition to the Affiliated Societies which publish the results of original local investigation, there are Associated Societies which need not so publish, but must consist of at least fifty members, and have been established not less than three years. The Delegate from an Affiliated Society must be a Member of the Association, that from an Associated Society may be an Associate, and although they had not quite the same privileges, all met on equal terms at the Conferences.

The meeting concluded with a vote of thanks to the Vice-Chairman for presiding.

A Bibliography of the Publications of Local Scientific Societies.

We venture to place before the Conference some suggestions for a piece of work which might be undertaken by the Committee of the Conference, on behalf of the British Association, to the great benefit and encouragement of the numerous amateur naturalists in the country, and a work which would even be useful to students and practical workers in science of higher pretensions. It is that a full bibliography of all papers contained in the Transactions and Journals of Local Scientific Societies of Great Britain and Ireland should be compiled and published. The value of such a work has forcibly suggested itself during the collation and binding up of the extensive series of these publications contained in the library of the Essex Field Club. It was abundantly evident how much information, the result of painstaking research, lies practically buried in these Transactions and Journals, information which cannot be obtained from any other sources. A classical instance may be mentioned of Mendel's work lying unknown for over thirty years.

Methods.—Some suggestions as to methods may be put forward. The British Association should supply index-slips to each society. The societies should undertake to catalogue (under Subjects and Authors) by means of such slips, the more important papers and notes which have been published in their Journals during the whole course of their existence. In doing this it should be borne in mind that even short papers may be of great importance as containing local facts or giving suggestions for future work. And the active officers of each society would be the best judges of the value of such papers and notes. The index-slips should then be forwarded to an expert bibliographer appointed by the British Association.

Each society should also furnish full information as to the titles and mode of publication of their Journals and other works published by them, together with notification of such libraries as are known to contain these books.

The bibliography might be published in two forms :—

(1) Ordinary book form printed on both sides of the paper.
(2) Slip-index form.

By means of the second mode of publication each society would be able to obtain an index of its own publications separately from the complete bibliography. As many societies have acquired extensive libraries by exchange, such a bibliography as the one suggested would be an invaluable adjunct to their catalogue of publications. Each society whose publications are thus indexed might be asked to subscribe for at least one copy of the bibliography, and inasmuch as this would serve in many cases as an index catalogue to their own libraries, doubtless a very considerable number of individual members would also subscribe. And a great number of public libraries, and libraries of societies, both here and in America, would also subscribe, so that in all probability the publication of the bibliography would pay for itself.

Although scientific periodicals other than those published by societies have been excluded from our scheme, the publishers of important scientific journals should be approached in order to see if it would be possible to extend the bibliography in this direction.

We merely put these terse suggestions forward as a basis for future discussion. The full working out of the scheme could be elaborated later. But we are fully impressed with the importance and interest of the work.

WM. COLE, *Hon. Secretary and Curator of the Essex Museum of Nat. Hist.*
HENRY WHITEHEAD, *Assistant Curator.*

A number of Corresponding Societies at the invitation of the Committee kindly sent copies of their publications, which were exhibited during the meeting of the French Association for the Advancement of Science, and were subsequently handed over to Dr. Loir.

The following Delegates attended the Conference and signed the attendance book :—

AFFILIATED SOCIETIES.

Cardiff Naturalists' Society	W. Mark Webb, F.L.S.
Essex Field Club	W. Mark Webb, F.L.S.
Glasgow Natural History Society	Mrs. Ewing.
Hertfordshire Natural History Society and Field Club	John Hopkinson, F.G.S.
Hull Geological Society	T. Sheppard, F.G.S.
Hull Scientific and Field Naturalists' Club . . .	T. Sheppard, F.G.S.
London : Quekett Microscopical Club	C. F. Rousselet.
London : Selborne Society	W. Mark Webb, F.L.S.
Manchester Microscopical Society	Mark L. Sykes, F.R.M.S.
South-Eastern Union of Scientific Societies . . .	A. W. Oke, F.G.S.
Yorkshire Naturalists' Union	T. Sheppard, F.G.S.

ASSOCIATED SOCIETIES.

Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B.
Hastings and St. Leonards Natural History Society .	George Willson.
Lewisham Antiquarian Society	Sir Edward Brabrook, C.B.
School Nature Study Union	W. Mark Webb, F.L.S.
Watford Camera Club	John Hopkinson, F.G.S.

Dr. F. A. Bather, F.R.S., representing the Museums Association, also attended the Conference.

On July 31 Dr. Garson, Mr. Hopkinson, Mr. Rousselet, Mr. Sheppard, and Mr. Webb attended a joint meeting of the Education Section of the French Association and the Conference of Delegates of the British Association called to consider the advisability of instituting a Conference similar to the British one.

Professor Julien Ray presided.

The following subjects were discussed :—

I. *Co-ordination of the Work of Local Societies.*

Dr. Loir explained the arrangements and the objects of the meetings held in connection with the British Association by the Delegates of Corresponding Societies.

He asked that the French Societies should be represented on the Council of the French Association for the Advancement of Science. Up to the present, this had not been the case. The French Association sent lecturers to the societies. With the Congress of learned Societies this is not the end in view.

Mr. Hopkinson (Hertfordshire Natural History Society), complying with the request of the President, gave a brief outline of the origin and early history of the Conferences of Delegates. He said that when he became a member of the British Association (in 1871) the President of any scientific society publishing Transactions, or in his absence a Delegate representing him, might claim to be a member of the General Committee at the meeting he attended, and the names of those whose claims were admitted, and of their societies, were printed separately in the list of members. It occurred to him that it might be to the advantage of the societies, and perhaps also of the Association, if these Delegates could meet to discuss matters relating chiefly to the management of their societies and the original work which might usefully be done by them, but as the rule stood if their Presidents were present their Secretaries could not be Delegates, and it was most important for the Secretaries to meet. Therefore at the meeting in 1879 he suggested to the Council of the Association the admission, as a member of the General Committee, of the Secretary of any duly qualified society as well as the President, and this suggestion being favourably received, a new rule adopting it

was duly passed. The first Conference was held at Swansea in 1880, and at this a Committee, consisting of Sir George Fordham and himself, was appointed to arrange for future Conferences. These were held, unofficially but with the sanction of the Council, at York in 1881, Southampton in 1882 (when Professor Meldola was added to the Committee), Southport in 1883, and Montreal in 1884. After this a Corresponding Societies Committee was officially appointed to manage the Conferences of Delegates, and the rules were altered, reducing the number of Delegates from each society to one, who need not be either President or Secretary of his society.

During the period of the unofficial Conferences, in 1882, a 'Circular referring to Subjects recommended for Investigation by Local Scientific Societies' was issued to the Corresponding and other Societies. This included the work of three Committees of the British Association and three subjects investigated by other societies or by individuals. In 1890 the Hertfordshire Natural History Society issued a circular extending that list, but omitting one Committee which had concluded its labours. This list was as follows :—A. Investigations conducted by Committees of the British Association : 1. Temperature of Surface-water. 2. Underground Waters. 3. Erosion of Sea-coast. 4. Erratic Boulders. 5. Geological Photography. 6. Disappearance of Native Plants. 7. Fresh-water Fauna and Flora. 8. Pre-historic Remains. B. Investigations conducted by other Societies or by Individual Observers : 1. Rainfall. 2. Phenological Phenomena. 3. Injurious Insects. 4. Archæological Survey of England. In each case brief instructions to observers were given, and also the names and addresses of those to whom the results were to be communicated. This circular, copies of which were sent to most of our provincial societies, appears to have done much to direct their attention and their energies into useful channels. He might add that the Corresponding Societies entered *con amore* into the project, each Society or Delegate subscribing 2*s*. 6*d*. per annum for the cost of the first five Conferences, chiefly expended in printing reports of them which were sent to all the societies.

Mr. Hopkinson then said that he would leave to Dr. Garson the duty of explaining the organisation of the Conferences of Delegates by the Corresponding Societies Committee as an official department of the British Association from the year 1885, and he concluded his remarks with an expression of gratification at the courteous request of the Association Française that we would explain our methods to them, and the compliment implied by this request.

Dr. Garson then gave some further details supplementing what had been said by Mr. Hopkinson, and pointing out the advantages derived by the Affiliated Societies.

Dr. Loir and Professor Ray : This is the object to be pursued in France ; we ought to follow the lead of the British Association and report what has been said at the Conference to the various French Societies.

II. *The Question of Units.*

Monsieur J. Henriet raised the question with regard to the changes which were to be made in the French Units.

Dr. Garson spoke of the recent introduction of the metric system in England into biological and medical investigations.

Mr. Hopkinson said that the British Meteorological Office had recently adopted the metric system in the publication in the 'Monthly Weather Report' of certain meteorological observations. From May 1 this year barometer readings were given in centibars and millibars (to the tenth of a millibar), rainfall observations in millimetres, and wind velocities in gales in metres per second.

Mr. Wilfred Mark Webb, at the request of the meeting, undertook to ask the Council of the British Association to give an opinion direct or through the appropriate Committee on the changes in the French system on receiving details of the same.

The result of the meeting was that it was decided to arrange a Conference at the meeting of the French Association in 1915 as nearly as was possible on the lines of the British one.

The Corresponding Societies of the British Association for 1914–1915.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Royal Technical College, Glasgow. Harry G. Cumming	240	2*s.* 6*d.*	2*s.* 6*d.*	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A. L. Stone, 2 St. Margaret's Road, and Rev. C. F. Thornewill, 15 St. Margaret's Rd., Oxford	300	None	5*s.*	Report, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. J. M. Finnigan.	200	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	A. W. Stelfox, Scottish Temperance Buildings, Donegall Square South, Belfast	363	5*s.*	5*s.*	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	300	10*s.*	7*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	121	None	10*s.* 6*d.* and 5*s.*	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. W. H. Foxall, F.R.G.S.	207	None	1*l.* 1*s.*	Proceedings, occasionally.
Bournemouth Natural Science Society, 1903	R. A. de Paiva, 13 Carysfort Road, Bournemouth	445	None	10*s.*	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	J. Colbatch Clark, 9 Marlborough Place, Brighton	140	None	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	Dr. O. V. Darbishire, The University, Bristol	160	5*s.*	10*s.* and 5*s.*	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	137	None	10*s.*	Transactions, annually.
Buchan Club, 1887	J. F. Tocher, D.Sc., Crown Mansions, Union Street, Aberdeen	180	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	A. Slator, D.Sc., 174 Ashley Road, Burton-on-Trent	220	None	6*s*	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto. J. R. Collins	550	None	2 dollars	Journal, bi-monthly.
Caradoc and Severn Valley Field Club, 1893	H. E. Forrest, 37 Castle Street, Shrewsbury	196	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Dr. Owen L. Rhys, 26 Windsor Place, Cardiff	500	None	12*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln	1,010	None	5*s.* and 2*s.* 6*d.*	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	The Museum, Public Buildings, Penzance. John B. Cornish	82	None	1*l.* 1*s.*	Transactions, annually.
Cornwall, Royal Institution of, 1818	Henry Jenner, F.S.A., County Museum, Truro	193	None	1*l.* 1*s.*	Journal, annually.
Cornwall, Royal Polytechnic Society, 1833	E. W. Newton, 4 Cross Street, Camborne, Cornwall	350	None	10*s.* upwards	Report, annually.
Cotteswold Naturalists' Field Club, 1846	L. Richardson, 10 Oxford Parade, Cheltenham	122	1*l.*	15*s.*	Proceedings, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. F. M. Roberts	150	None	10*s.*, 5*s.*, and 2*s.* 6*d.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., Milton Abbey Vicarage, Dorset	400	10*s.*	10*s.*	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	C. B. Moffat, B.A., 23 Gardiner's Place, Dublin	85	5*s.*	5*s.*	'Irish Naturalist,' monthly; Report, annually.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	G. W. Shirley, Ewart Public Library, Dumfries	405	None	5*s.*	Transactions and Proceedings, annually.
Durham, University of, Philosophical Society, 1896	A. A. Hall and E. M. Eden, Armstro College, Newcastle-on-Tyne	200	None	10*s.*	Proceedings, half-yearly.
East Anglia, Prehistoric Society of, 1908	W. G. Clarke, 12 St. Philip's Road, Norwich	220	None	5*s.*	Proceedings, annually.
East Kent Scientific and Natural History Society, 1857	A. Lander, 17 High Street, Canterbury	60	None	10*s.* and 5*s.*	Transactions, annually.
Eastbourne Natural History, Photographic, and Literary Society, 1867	Miss Jay, Technical Institute, Eastbourne	180	2*s.* 6*d.*	5*s.*	Transactions and Journal, quarterly.
Edinburgh Field Naturalists' and Microscopical Society, 1869	Allan A. Pinkerton, 19 Shandwick Place, Edinburgh	234	None	5*s.*	Transactions, annually.
Edinburgh Geological Society, 1834	India Buildings, Edinburgh. W. T. Gordon	250	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	H. B. Mackintosh, Redhythe, Elgin	149	None	5*s.*	Transactions, occasionally.
Essex Field Club, 1880	Essex Museum of Natural History, Romford Road, Stratford. W. Cole	300	None	15*s.*	'Essex Naturalist,' quarterly; 'Year-book,' annually; 'Special Memoirs,' &c., occasionally.
Glasgow, Geological Society of, 1858	Peter Macnair, F.R.S.E., 207 Bath Street, Glasgow	250	None	10*s.*	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851	Alex. Ross, 409 Great Western Road, Glasgow	269	None	7*s.* 6*d.*	'Glasgow Naturalist,' quarterly.
Glasgow, Royal Philosophical Society of, 1802	Prof. Peter Bennett, 207 Bath Street, Glasgow	1,000	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	5*s.*	10*s.* 6*d.*	Proceedings, annually.
Hampstead Scientific Society, 1899	C. O. Bartrum, B.Sc., and R. W. Wylie, M.A., 32 Willoughby Road, Hampstead, N.W.	374	None	Minimum 5*s.*	Report and Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	D. Hill, Herga, Watford	166	None	10*s.*	Transactions, annually.
Holmesdale Natural History Club, 1857	Miss M. C. Crosfield, Undercroft, Reigate	71	None	10*s.* and 5*s.*	Proceedings, occasionally.
Hull Geological Society, 1889	J. W. Stather, F.G.S., Newland Park, Hull	73	None	5*s.*	Transactions, occasionally.
Hull Scientific and Field Naturalists' Club, 1886	T. Stainforth, B.A., The Museum, Hull	140	None	5*s.*	Transactions, annually.
Institution of Mining Engineers, 1889	Percy Strzelecki, 39 Victoria Street, London, S.W.	3,600	None	None	Transactions, monthly.
Ireland, Statistical and Social Inquiry Society of, 1847	W. Lawson, Dr. N. M. Falkiner, and Herbert Wood, 93 Stephen's Green, Dublin	80	None	1*l.*	Journal, annually.
Leeds Geological Association, 1873	E. Hawkesworth, Cross Gates, Leeds	123	None	5*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. F. B. Lott, 7 Stoneygate Avenue, Leicester	275 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, annually.
Lincolnshire Naturalists' Union, 1893	Arthur Smith, F.L.S., City and County Museum, Lincoln	112	None	5*s.*	Transactions, annually.
Liverpool Biological Society 1886	J. A. Clubb, D.Sc., Free Public Museum, Liverpool	80	None	1*l.* 1*s.*	Proceedings and Transactions, annually.

Liverpool Botanical Society, 1906	Miss M. B. Barr, 25 Deane Road, Fairfield, Liverpool	120	None	5s.	Proceedings, biennially; Transactions, occasionally.
Liverpool Engineering Society, 1875	T. R. Wilton, M.A., 1 Crosshall Street, Liverpool	599	None	1l. 1s., 10s. 6d., and 5s.	Transactions and Report, annually.
Liverpool Geographical Society, 1891	A. Ellis Cookson, 14 Hargreave's Buildings, Liverpool	600	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions and Report, annually.
Liverpool Geological Society, 1858	Royal Institution. T. A. Jones	75	None	10s. 6d.	Proceedings, annually.
London: Quekett Microscopical Club, 1865	Jas. Burton, 8 Somali Road, West Hampstead, N.W.	450	None	10s.	Journal, half-yearly.
London: Selborne Society, 1885	42 Bloomsbury Square, W.C. W. M. Webb, F.L.S.	3,111	None	5s.	'Selborne Magazine,' monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	P. W. Cowley, Ramsey, Isle of Man	243	2s. 6d.	7s. 6d. and 5s.	Proceedings and Transactions, annually.
Manchester Geographical Society, 1884	E. Steinthal, 16 St. Mary's Parsonage, Manchester	708	None	Members 1l. 1s.; Associates 10s. 6d.	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Sydney A. Smith	400	None	2l. 2s., 1l. 5s., and 1l.	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880	Frederick Dishley, 14 Westwood Street, Moss Side, Manchester	190	5s.	6s.	Transactions and Report, annually.
Manchester Statistical Society, 1833	F. Vernon Hansford, 3 York Street, Manchester	170	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History Society, 1864	E. Meyrick, F.R.S., Marlborough College	250	1s. 6d.	5s. and 1s.	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Midland Road, Derby	380	1l. 1s.	2l. 2s. and 1l.	Transactions of Institution of Mining Engineers, monthly.
Museums Association, 1889	E. E. Lowe, B.Sc., Museum and Art Gallery, Leicester	Members (Insts.) 111	None	21s.	Museums Journal, monthly.
		Associates (Persons) 119	None	10s. 6d.	Museums Directory, occasionally.
Norfolk and Norwich Naturalists' Society, 1869	S. H. Long, M.D., 37 St. Giles Street, Norwich	290	None	6s.	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne. Lawrence Austin	1,273	None	25s. and 42s.	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865	W. Wells Bladen, Stone, Staffs.	678	5s.	5s.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 17 St. Matthew's Parade, Northampton	230	None	10s.	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. C. E. Robson and J. A. Richardson	415	None	21s.	Transactions, annually.
Nottingham Naturalists' Society, 1852	Prof. J. W. Carr, M.A., University College, Nottingham	116	2s. 6d.	5s.	Report and Transactions, annually.
Paisley Philosophical Institution, 1808	J. Gardner, 3 County Place, Paisley	552	5s.	7s. 6d.	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867	Tay Street, Perth. S. T. Ellison	330	None	5s. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	J. Reginald Ashworth, D.Sc., 55 King Street South, Rochdale	240	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878	John Hepworth, Linden House, Rochester	130	None	5s.	'Rochester Naturalist,' quarterly.
Sheffield Naturalists' Club, 1870	C. Bradshaw, Public Museum, and A. Brittain, 47 Bank Street, Sheffield	105	None	5s.	Report, bi-annually; Proceedings, occasionally.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, Rev. E. H. Bates Harbin, and C. Tite	925	10*s*. 6*d*.	10*s*. 6*d*.	Proceedings, annually.
South Africa, Royal Society of, 1906	G. M. Clark, South African Museum, Cape Town	207	None	2*l*.	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	William Martin, LL.D., F.S.A., 2 Garden Court, Temple, E.C.	about 11,000	None	Minimum 5*s*.	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society	A. H. Garstang, 82 Forest Road, Southport	200	None	7*s*. 6*d*.	Proceedings, occasionally.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham	150	1*l*. 1*s*. and 10*s*. 6*d*.	42*s*. and 21*s*.	Transactions of Institution of Mining Engineers, monthly.
Torquay Natural History Society, 1844	Harford J. Lowe, F.G.S., The Museum, Torquay	179	10*s*. 6*d*.	1*l*. 1*s*.	Journal, annually.
Tyneside Geographical Society, 1887	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A.	1,000	None	21*s*. and 10*s*.	Journal, quarterly.
Vale of Derwent Naturalists' Field Club, 1887	J. E. Patterson, 2 East Avenue, Benton, Newcastle-on-Tyne	150	None	2*s*. 6*d*.	Transactions, occasionally.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	70	2*s*. 6*d*.	5*s*.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1852	Woolhope Club Room, Free Library, Hereford. T. Hutchinson	220	10*s*.	10*s*.	Transactions, occasionally.
Worcestershire Naturalists' Club, 1847	Education Offices, Worcester. F. T. Spackman, F.G.S.	180	10*s*.	5*s*.	Transactions, annually.
Yorkshire Geological Society, 1837	Albert Gilligan, The University, Leeds	250	None	13*s*.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	The Museum, Hull. T. Sheppard, F.G.S.	380 and 3,050 Associates	None	10*s*. 6*d*.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Museum, York. C. E. Elmhirst	350	None	2*l*. and 1*l*.	Report, annually.

Associated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Balham and District Antiquarian and Natural History Society, 1897	A. L. Barron, Clophill, Wallington, Surrey	82	None	5*s*.	Report, annually; Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	W. L. Page, 5 Cavendish Street, Barrow	255	None	5*s*. and 2*s*. 6*d*.	Report and Proceedings, annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. Miss L. B. Morris	66	2*s*. 6*d*.	3*s*. 6*d*.	—
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, 2 Vincent Street, Bradford	80	1*s*.	4*s*.	—
Bradford Scientific Association, 1875	W. Newbould, 34 Burnett Avenue, Bradford	140	None	5*s*. and 2*s*. 6*d*.	—
Catford and District Natural History Society, 1897	W. H. Griffin, 94 Ravensbourne Road, Catford, S.E.	76	None	5*s*.	—

Dunfermline Naturalists' Society, 1902	Robert Somerville, B.Sc., 38 Cameron Street, Dunfermline	165	None	5s.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Coley Lodge, 21 Florence Road, Ealing, W.	146	None	10s. and 2s. 6d.	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. F. W. Sowerby	78	None	4s.	—
Halifax Scientific Society, 1874	J. H. Lumb, 32 Undercliffe Terrace, Halifax	180	None	2s. 6d.	—
Hastings and St. Leonards Natural History Society, 1893	W. de Muller, B.A., 14 St. Matthew's Gardens, St Leonards-on-Sea	430	1s.	3s. 6d.	'Hastings and East Sussex Naturalist,' occasionally.
Hawick Archæological Society, 1856	J. J. Vernon, 81 High Street, Hawick	300	None	2s. 6d.	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	Thomas Wallace, Ellerslie, Inverness	180	None	5s.	Transactions, occasionally.
Ipswich and District Field Club, 1907	F. J. Fletcher, The Drift, Britannia Road, Ipswich	125	None	2s. 6d.	Journal, occasionally.
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. William Mansbridge	99	None	5s.	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Edward J. T. Ingle, 18 Strattan Street, Leeds	103	None	5s. and 3s. 6d.	Proceedings, occasionally.
Lewisham Antiquarian Society, 1885	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	73	None	5s.	Transactions, occasionally.
Liverpool Microscopical Society, 1868	Royal Institution, Liverpool. R. Croston	64	None	10s. 6d.	Report, annually.
Llandudno and District Field Club, 1906	L. S. Underwood, Brinkburn, Llandudno	157	None	5s.	Proceedings, annually.
London: London Natural History Society, 1913	J. Ross, 18 Queen's Grove Road, Chingford, N.E.	255 Members and Assoc.	2s. 6d.	5s. and 2s. 6d.	—
London: South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S.E. Stanley Edwards, F.L.S., and H. J. Turner, F.E.S.	180	2s. 6d.	10s.	Proceedings, annually.
Maidstone and Mid-Kent Natural History and Philosophical Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	81	None	10s.	Report, occasionally.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes and Frederick Emley	3,100	None	1l. 1s.	—
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. F. Chadderton	420	None	5s.	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	A. J. Burnley, 43 Moorland Road, Scarborough	105	None	1l. and 10s.	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,670	None	2s. 6d.	'School Nature Study,' five times a year.
Southport Society of Natural Science, 1890	P. H. Christian, 9 Russell Road, Southport	222	None	5s.	Report, annually.
Teign Naturalists' Field Club, 1858	John S. Amery, Druid, Ashburton, Devon	120	None	2s. 6d.	Report, annually.
Tunbridge Wells Literary and Natural History Society, 1884	Dr. D. Davies, 8 Lonsdale Gardens, Tunbridge Wells	129	None	10s. 6d. and 5s.	Report, annually.
Watford Camera Club and Photographic Society, 1902	F. H. Haines, 100 High Street, Watford	70	None	10s. 6d.	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1914.

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Prof. T. G. Bonney, Sc.D., F.R.S.
Sir W. Ramsay, K.C.B., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.
Sir Oliver Lodge, D.Sc., F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Prof. T. G. Bonney, Sc.D., F.R.S.
A. Vernon Harcourt, D.C.L., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir E. A. Schäfer, LL.D., F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.
Major P. A. MacMahon, F.R.S.

AUDITORS.

Sir Edward Brabrook, C.B.
Professor H. McLeod, LL.D., F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1914.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, London, W.

Year of Election.

1905. *à-Ababrelton, Robert, F.R.G.S., F.S.S. P.O. Box 322, Pietermaritzburg, Natal. Care of Royal Colonial Institute, Northumberland-avenue, W.C.
1887. *ABBE, Professor CLEVELAND. Local Office, U.S.A. Weather Bureau, Washington, U.S.A.
1914. §Abbott, Hon. R. H. S. Rowan-street, Bendigo, Victoria.
1881. *Abbott, R. T. G. Whitley House, Malton.
1885. *ABERDEEN, The Marquis of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Marchioness of. Haddo House, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Pres. L, 1903; Council, 1884–89, 1902–05, 1906–12.) Measham Hall, Leicestershire.
1905. ‡Aburrow, Charles. P.O. Box 534, Johannesburg.
1913. §Ackland, T. G., F.I.A. 5–6 Clement's Inn, Strand, W.C.
1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Walwood, Banstead, Surrey.
1894. *ACLAND, HENRY DYKE, F.G.S. Chy-an-Mor, Gyllyngvase, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W.

Year of Election.

1904. ‡Acton, T. A. 41 Regent-street, Wrexham.
1898. ‡Acworth, W. M., M.A. (Pres. F, 1908.) The Albany, W.
1901. ‡Adam, J. Miller. 15 Walmer-crescent, Glasgow.
1887. ‡Adami, J. G., M.A., M.D., F.R.S., Professor of Pathology in McGill University, Montreal, Canada.
1901. §Adams, John, M.A., B.Sc., LL.D. (Pres. L, 1912), Professor of Education in the University of London. 23 Tanza-road, Hampstead, N.W.
1904. ‡Adams, W. G. S., M.A. Department of Agriculture, Upper Merrion-street, Dublin.
1869. *Adams, William Grylls, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880; Council, 1878–85.) Heathfield, Broadstone, Dorset.
1908. *Adamson, R. Stephen. The University, Manchester.
1913. ‡Addison, W. H. F. Medical School, The University of Pennsylvania.
1890. ‡Adeney, W. E., D.Sc., F.C.S. Burnham, Monkstown, Co. Dublin.
1913. §Adeney, Rev. Professor W. F., M.A., D.D. Lancashire College, Whalley Range, Manchester.
1913. §Adeney, Mrs. Lancashire College, Whalley Range, Manchester.
1899. *Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
1908. §Adkin, Robert. 4 Lingard's-road, Lewisham, S.E.
1912. ‡Afanassieff, Apollo. Physical Institute, Imperial University, Petrograd.
1908. *Agar, W. E., M.A. Natural History Department, The University, Glasgow.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1906. §Aikman, J. A. 6 Glencairn-crescent, Edinburgh.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1909. *Aird, John. Canadian Bank of Commerce, Toronto, Canada.
1911. §Airey, John R., M.A., B.Sc. 73 Claremont-road, Forest Gate, E.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §Aitken, John, LL.D., F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1901. ‡Aitken, Thomas, M.Inst.C.E. County Buildings, Cupar-Fife.
1884. *Alabaster, H. Milton, Grange-road, Sutton, Surrey.
1886. *Albright, G. S. Broomsberrow Place, Ledbury.
1905. ‡Albright, Miss. Finstal Farm, Finstal, Bromsgrove, Worcestershire.
1913. ‡Albright, W. A. 29 Frederick-road, Edgbaston, Birmingham.
1900. *Aldren, Francis J., M.A. The Lizans, Malvern Link.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 39 Victoria-street, Westminster, S.W.
1905. *Alexander, J. Abercromby. 24 Lawn-crescent, Kew.
1888. *Alexander, Patrick Y. 3 Whitehall-court, S.W.
1910. *Alexander, W. B., B.A. Western Australian Museum, Perth, West Australia.
1891. *Alford, Charles J., F.G.S. Hotel Victoria, Rome.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1914. §Allan, Edward F., B.A. 37 Wattletree Road, Malvern, Victoria.
1901. *Allan, James A. 21 Bothwell-street, Glasgow.
1904. *Allcock, William Burt. Emmanuel College, Cambridge.
1879. *Allen, Rev. A. J. C. 34 Lensfield-road, Cambridge.
1898. §Allen, Dr. E. J., F.R.S. The Laboratory, Citadel Hill, Plymouth.
1891. ‡Allen, H. A., F.G.S. 28 Jermyn-street, S.W.
1907. *Allorge, M. M., L. ès Sc., F.G.S. Villa St. Germain, Louviers, France.

Year of Election.

1912. *Allworthy, S. W., M.A., M.D. The Manor House, Antrim-road, Belfast.
1882. *Alverstone, The Right Hon. Lord, G.C.M.G., LL.D., F.R.S. Winterfold, Cranleigh, Surrey.
1887. ‡Alward, G. L. Enfield Villa, Waltham, Grimsby, Yorkshire.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1909. ‡Ami, H. M., M.D. Ottawa, Canada.
1884. ‡AMI, HENRY, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
1914. §Anderson, Miss Adelaide M. Home Office, S.W.
1910. ‡Anderson, Alexander. Tower House, Dore, near Sheffield.
1905. *Anderson, C. L. P.O. Box 2162, Johannesburg.
1912. ‡Anderson, E. M. 43 Ladysmith-road, Edinburgh.
1908. ‡Anderson, Edgar. Glenavon, Merrion-road, Dublin.
1885. *ANDERSON, HUGH KERR, M.A., M.D., F.R.S. Caius College, Cambridge.
1914. §Anderson, J. R. V. School of Mines, Bendigo, Victoria.
1901. *Anderson, James. 166 Buchanan-street, Glasgow.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1899. *Anderson, Miss Mary Kerr. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 5 Westminster-chambers, S.W.
1901. *Anderson, Dr. W. Carrick. 7 Scott-street, Garnethill, Glasgow.
1908. ‡Anderson, William. Glenavon, Merrion-road, Dublin.
1911. ‡Andrade, E. N. da C. University College, Gower-street, W.C.
1907. ‡Andrews, A. W. Adela-avenue, West Barnes-lane, New Malden, Surrey.
1909. ‡Andrews, Alfred J. Care of Messrs. Andrews, Andrews, & Co., Winnipeg, Canada.
1895. ‡ANDREWS, CHARLES W., B.A., D.Sc., F.R.S. British Museum (Natural History), S.W.
1914. §Andrews, E. C. Geological Branch, Department of Mines, Sydney, N.S.W.
1909. ‡Andrews, G. W. 433 Main-street, Winnipeg, Canada.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1877. §ANGELL, JOHN, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1912. §Angus, Miss Mary. 354 Blackness-road, Dundee.
1886. ‡Ansell, Joseph. 27 Bennett's-hill, Birmingham.
1901. ‡Arakawa, Minozi. Japanese Consulate, 84 Bishopsgate-street Within, E.C.
1900. *ARBER, E. A. NEWELL, M.A., F.L.S. 52 Huntingdon-road, Cambridge.
1904. *ARBER, Mrs. E. A. NEWELL, D.Sc., F.L.S. 52 Huntingdon-road, Cambridge.
1913. ‡Archer, J. Hillside, Crowcombe, West Somerset.
1913. *Archer, R. L., M.A., Professor of Education in University College, Bangor. Plas Menai, Bangor.
1894. ‡Archibald, A. Holmer, Court-road, Tunbridge Wells.
1909. §Archibald, Professor E. H. Bowne Hall of Chemistry, Syracuse University, Syracuse, New York, U.S.A.
1909. ‡Archibald, H. Care of Messrs. Machray, Sharpe, & Dennistoun, Bank of Ottawa Chambers, Winnipeg, Canada.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1908. ‡Armstrong, E. C. R., M.R.I.A., F.R.G.S. Cyprus, Eglinton-road, Dublin.
1903. *ARMSTRONG, E. FRANKLAND, D.Sc., Ph.D. Greenbank, Greenbank-road, Latchford, Warrington.

Year of Election.

1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S. (Pres. B, 1885, 1909; Pres. L, 1902; Council, 1899–1905, 1909- .) 55 Granville-park, Lewisham, S.E.
1909. ‡Armstrong, Hon. Hugh. Parliament Buildings, Kennedy-street, Winnipeg, Canada.
1905. ‡Armstrong, John. Kamfersdam Mine, near Kimberley, Cape Colony.
1905. ‡ARNOLD, J. O., F.R.S., Professor of Metallurgy in the University of Sheffield.
1893. *ARNOLD-BEMROSE, H. H., Sc.D., F.G.S. Ash Tree House, Osmaston-road, Derby.
1915. §Arnold-Bernard, Pierre. 662 West End-avenue, New York City, U.S.A.
1904. ‡Arunachalam, P. Ceylon Civil Service, Colombo, Ceylon.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1903. *ASHBY, THOMAS, M.A., D.Litt. The British School, Rome.
1909. ‡Ashdown, J. H. 337 Broadway, Winnipeg, Canada.
1907. ‡ASHLEY, W. J., M.A. (Pres. F, 1907), Professor of Commerce in the University of Birmingham. 3 Yateley-road, Edgbaston, Birmingham.
Ashworth, Henry. Turton, near Bolton.
1903. *Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
1914. *Ashworth, Mrs. J. H. 4 Cluny-terrace, Edinburgh.
1890. ‡Ashworth, J. Reginald, D.Sc. 55 King-street South, Rochdale.
1875. *Aspland, W. Gaskell. Care of Messrs. Boustead & Clarke, Mombasa, East Africa.
1896. *Assheton, Richard, M.A., F.R.S., F.L.S. Grantchester, Cambridge.
1905. ‡Assheton, Mrs. Grantchester, Cambridge.
1908. §ASTLEY, Rev. H. J. DUKINFIELD, M.A., Litt.D. East Rudham Vicarage, King's Lynn.
1898. *Atkinson, E. Cuthbert. 5 Pembroke-vale, Clifton, Bristol.
1894. *Atkinson, Harold W., M.A. West View, Eastbury-avenue, Northwood, Middlesex.
1906. ‡Atkinson, J. J. Cosgrove Priory, Stony Stratford.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1907. ‡Atkinson, Robert E. Morland-avenue, Knighton, Leicester.
1881. ‡ATKINSON, ROBERT WILLIAM, F.C.S., F.I.C. (Local Sec. 1891.) 44 Stuart-street, Cardiff.
1906. §AUDEN, G. A., M.A., M.D. The Education Office, Edmund-street, Birmingham.
1907. §Auden, H. A., D.Sc. 13 Broughton-drive, Grassendale, Liverpool.
1903. ‡AUSTIN, CHARLES E. 37 Cambridge-road, Southport.
1912. §Austin, Percy C. 101 Norwood-road, Herne Hill, S.E.
1909. ‡Axtell, S. W. Stobart Block, Winnipeg, Canada.

1914. §Baber, Z., Professor of Geography and Geology in the University of Chicago, U.S.A.
1883. *Bach-Gladstone, Madame Henri. 147 Rue de Grenelle, Paris.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡Baden-Powell, Major B. 32 Prince's-gate, S.W.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.
1914. §Bage, Charles, M.A., M.D. 139 Collins-street, Melbourne.

Year of Election.

1914. §Bage, Miss Freda. Women's College, Brisbane, Australia.
1908. *Bagnall, Richard Siddoway. Hope Department of Zoology, University Museum, Oxford.
1905. ‡Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1883. *Bailey, Charles, M.Sc., F.L.S. Haymesgarth, Cleeve Hill S.O., Gloucestershire.
1887. *Bailey, G. H., D.Sc., Ph.D. Edenmor, Kinlochleven, Argyll, N.B.
1905. *Bailey, Harry Percy. Montrose, Northdown, Margate.
1914. §Bailey, P. G. 4 Richmond-road, Cambridge.
1905. ‡Bailey, Right Hon. W. F., C.B. Land Commission, Dublin.
1894. *Baily, Francis Gibson, M.A. Newbury, Colinton, Midlothian.
1878. ‡Baily, Walter. 4 Roslyn-hill, Hampstead, N.W.
1914. §Bainbridge, F. A., M.D., Professor of Physiology in the University of Durham, Newcastle-on-Tyne.
1905. *Baker, Sir Augustine. 56 Merrion-square, Dublin.
1913. *Baker, Bevan B., B.Sc. Frontenac, Donnington-road, Harlesden, N.W.
1910. §Baker, H. F., Sc.D., F.R.S. (Pres. A., 1913), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. St. John's College, Cambridge.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1911. §Baker, Miss Lilian, M.Sc. Bryn Deiniol, Bangor.
1913. *‡Baker, Ralph Homfeld. Cambridge.*
1907. ‡Baldwin, Walter. 5 St. Alban's-street, Rochdale.
1904. ‡Balfour, The Right Hon. A. J., D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. (President, 1904.) Whittingehame, Prestonkirk, N.B.
1894. ‡Balfour, Henry, M.A. (Pres. H, 1904.) Langley Lodge, Headington Hill, Oxford.
1905. ‡Balfour, Mrs. H. Langley Lodge, Headington Hill, Oxford.
1875. ‡Balfour, Isaac Bayley, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1894; K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡Balfour, Lewis. 11 Norham-gardens, Oxford.
1905. ‡Balfour, Miss Vera B. Dawyck, Stobo, N.B.
1878. *Ball, Sir Charles Bent, Bart., M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1913. *Ball, Sidney, M.A. St. John's College, Oxford.
1908. ‡Ball, T. Elrington. 6 Wilton-place, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1914. §Balsillie, J. Greene. P.M.G.'s Department, Melbourne.
1890. ‡Bamford, Professor Harry, M.Sc. 30 Falkland-mansions, Glasgow.
1909. ‡Bampfield, Mrs. E. 309 Donald-street, Winnipeg, Canada.
1912. *Bancroft, Miss Nellie, B.Sc., F.L.S. 260 Normanton-road, Derby.
1898. ‡Bannerman, W. Bruce, F.S.A. 4 The Waldrons, Croydon.
1909. ‡Baragar, Charles A. University of Manitoba, Winnipeg, Canada.
1910. ‡Barber, Miss Mary. 13 Temple Fortune Court, Hendon, N.W.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1902. ‡Barcroft, H., D.L. The Glen, Newry, Co. Down.
1902. ‡Barcroft, Joseph, M.A., B.Sc., F.R.S. King's College, Cambridge.

Year of Election.

1911. †Barger, George, M.A., D.Sc., Professor of Chemistry in the Royal Holloway College. Malahide, Englefield Green, Surrey.
1904. §Barker, B. T. P., M.A., Professor of Agricultural Biology in the University of Bristol. Fenswood, Long Ashton, Bristol.
1906. *Barker, Geoffrey Palgrave. Henstead Hall, Wrentham, Suffolk.
1899. §Barker, John H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1882. *Barker, Miss J. M. Sunny Bank, Scalby, Scarborough.
1910. *Barker, Raymond Inglis Palgrave. Henstead Hall, Wrentham, Suffolk.
1913. §Barling, Dr. Gilbert. Blythe Court, Norfolk-road, Edgbaston, Birmingham.
1909. ‡Barlow, Lieut.-Colonel G. N. H. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1889. ‡Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
1905. *Barnard, Miss Annie T., M.D., B.Sc. Care of W. Barnard, Esq., 3 New-court, Lincoln's Inn, W.C.
1881. *Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1904. ‡Barnes, Rev. E. W., M.A., Sc.D., F.R.S. Trinity College, Cambridge.
1907. §Barnes, Professor H. T., Sc.D., F.R.S. McGill University, Montreal, Canada.
1909. *Barnett, Miss Edith A. Holm Leas, Worthing.
1913. §Barnett, Thomas G. The Hollies, Upper Clifton-road, Sutton Coldfield.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. (Pres. G, 1912.) Caxton-street, Anniesland, Glasgow.
1902. *Barr, Mark. Gloucester-mansions, Harrington-gardens, S.W.
1904. ‡Barrett, Arthur. 6 Mortimer-road, Cambridge.
1872. *Barrett, Sir W. F., F.R.S., F.R.S.E., M.R.I.A. 6 De Vesci-terrace, Kingstown, Co. Dublin.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Rev. Mark J., M.A., F.L.S., F.R.G.S. The Rectory, Duloe S.O., Cornwall.
1893. *Barrow, George, F.G.S. 202 Brecknock-road, Tufnell Park, N.
1913. ‡Barrow, Harrison. 57 Wellington-street, Edgbaston, Birmingham.
1913. ‡Barrow, Louis. 155 Middleton Hall-road, King's Norton.
1913. ‡Barrow, Walter. 13 Ampton-road, Edgbaston, Birmingham.
1908. ‡Barry, Gerald H. Wiglin Glebe, Carlow, Ireland.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. Newington House, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1909. ‡Bartleet, Arthur M. 138 Hagley-road, Edgbaston, Birmingham.
1909. ‡Bartlett, C. Bank of Hamilton-building, Winnipeg, Canada.
1914. §Barton, E. C. City Electric Light Company, Brisbane, Australia.
1893. *Barton, Edwin H., D.Sc., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1908. ‡Barton, Rev. Walter John, M.A., F.R.G.S. Epsom College, Surrey.
1904. *Bartrum, C. O., B.Sc. 32 Willoughby-road, Hampstead, N.W.
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.

Year of Election.

1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, N.
1911. *BASSETT, HENRY, jun., D.Sc., Ph.D. University College, Reading.
1889. ‡BASTABLE, Professor C. F., M.A., F.S.S. (Pres. F, 1894.) 52 Brighton-road, Rathgar, Co. Dublin.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. Fairfield, Chesham Bois, Bucks.
1912. ‡Bastian, Staff-Surgeon William, R.N. Chesham Bois, Buckinghamshire.
1883. ‡BATEMAN, Sir A. E., K.C.M.G. Woodhouse, Wimbledon Park, S.W.
1905. *Bateman, Mrs. F. D. The Rectory, Minchinhampton.
1907. *BATEMAN, HARRY. The University, Manchester.
1914. §Bates, Mrs. Daisy M. 210 Punt-road, Prahran, Victoria.
1884. ‡BATESON, Professor WILLIAM, M.A., F.R.S. (PRESIDENT; Pres. D, 1904.) The Manor House, Merton, Surrey.
1914. §Bateson, Mrs. The Manor House, Merton, Surrey.
1881. *BATHER, FRANCIS ARTHUR, M.A., D.Sc., F.R.S., F.G.S. British Museum (Natural History), S.W.
1906. §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1904. ‡Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1909. ‡Bawlf, Nicholas. Assiniboine-avenue, Winnipeg, Canada.
1913. §Bawtree, A. E., F.R.P.S. Lynton, Manor Park-road, Sutton, Surrey.
1912. *Baxter, Miss Evelyn V. Roselea, Kirkton of Largo, Fife.
1912. *Bayliss, W. M., M.A., D.Sc., F.R.S., Professor of General Physiology in University College, London, W.C.
1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Kilmorie, Ilsham-drive, Torquay, Devon.
1909. *BEADNELL, H. J. LLEWELLYN, F.G.S. Hafod, Llandinam, Montgomeryshire.
1905. ‡Beare, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
1889. §BEARE, Professor T. HUDSON, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1905. ‡Beare, Mrs. T. Hudson. 10 Regent-terrace, Edinburgh.
1904. ‡Beasley, H. C. 25A Prince Alfred-road, Wavertree, Liverpool.
1905. ‡Beattie, Professor J. C., D.Sc., F.R.S.E. South African College, Cape Town.
1900. ‡Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds.
1885. *BEAUMONT, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C.
1914. §Beaven, E. S. Eastney, Warminster.
1914. §Beaven, Miss M. J. Eastney, Warminster.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. Cheney Cottage, Headington, Oxford.
1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector of the Zoological Society of London, Regent's Park, N.W.
1911. ‡Beddow, Fred, D.Sc., Ph.D. 2 Pier-mansions, Southsea.
1904. *Bedford, T. G., M.A. 13 Warkworth-street, Cambridge.
1891. ‡Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1901. *BEILBY, G. T., LL.D., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.
1905. ‡Beilby, Hubert. 11 University-gardens, Glasgow.

Year of
Election.
1914. §Belas, Philip E., B.A. University College, Cork.
1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W.
1909. ‡BELL, C. N. (Local Sec. 1909.) 121 Carlton-street, Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. British Museum, S.W.
1900. *Bell, Henry Wilkinson. Beech Cottage, Rawdon, near Leeds.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1914. §Bell, William Reid, M.Inst.C.E. Burnie, Tasmania.
1908. *Bellamy, Frank Arthur, M.A., F.R.A.S. University Observatory, Oxford.
1904. ‡Bellars, A. E. Magdalene College, Cambridge.
1913. *Belliss, John, M.I.M.E. Darlinghurst, Carpenter-road, Edgbaston, Birmingham.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. ‡Bennett, Professor Peter. 207 Bath-street, Glasgow.
1909. *Bennett, R. B., K.C. Calgary, Alberta, Canada.
1909. ‡Benson, Miss C. C. Terralta, Port Hope, Ontario, Canada.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *BENSON, Miss MARGARET J., D.Sc. Royal Holloway College, Englefield Green.
1914. §Benson, W. Killara, Sydney, N.S.W.
1887. *Benson, Mrs. W. J. 5 Wellington-court, Knightsbridge, S.W.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1904. ‡BENTLEY, B. H., M.A., Professor of Botany in the University of Sheffield.
1905. *Bentley, Wilfred. The Dene, Kirkheaton, Huddersfield.
1908. ‡*Benton, Mrs. Evelyn M. Kingswear, Hale, Altrincham, Cheshire.*
1896. *Bergin, William, M.A., Professor of Natural Philosophy in University College, Cork.
1894. §BERKELEY, The Earl of, F.R.S., F.C.S. (Council, 1909–10.) Foxcombe, Boarshill, near Abingdon.
1905. *BERNACCHI, L. C., F.R.G.S. 54 Inverness-terrace, W.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1898. §Berridge, Miss C. E. 48 Stratford-road, Marloes-road, Kensington, W.
1894. §BERRIDGE, DOUGLAS, M.A., F.C.S. The College, Malvern.
1908. *Berridge, Miss Emily M. Dunton Lodge, The Knoll, Beckenham.
1914. §Berridge, Miss Isabel. 7 The Knoll, Beckenham, Kent.
1908. *Berry, Arthur J. 14 Regent-street, Cambridge.
1904. §Berry, R. A., Ph.D., West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1914. §Berry, Professor R. J. A., M.D. The University, Carlton, Melbourne.
1905. ‡Bertrand, Captain Alfred. Champel, Geneva.
1862. ‡BESANT, WILLIAM HENRY, M.A., Sc.D., F.R.S. St. John's College, Cambridge.
1913. ‡Bethune-Baker, G. T. 19 Clarendon-road, Edgbaston, Birmingham.
1880. *BEVAN, Rev. JAMES OLIVER, M.A., F.S.A., F.G.S. Chillenden Rectory, Canterbury.
1913. §Bevan, Mrs. Hillside, Egham.
1884. *Beverley, Michael, M.D. The Shrubbery, Scole, Norfolk.
1913. §Bewlay, Hubert. The Lindens, Moseley, Birmingham.
1903. ‡Bickerdike, C. F. 1 Boverney-road, Honor Oak Park, S.E.
1870. ‡Bicketon, Professor A. W. 18 Pembridge-mansions, Moscow-road, W.

Year of Election.

1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1910. ‡*Biddlecombe, A. 50 Grainger-street, Newcastle-on-Tyne.*
1911. ‡BILES, Sir JOHN H., LL.D., D.Sc. (Pres. G., 1911), Professor of Naval Architecture in the University of Glasgow. 10 University-gardens, Glasgow.
1898. ‡Billington, Charles. Heimath, Longport, Staffordshire.
1901. *Bilsland, Sir William, Bart., J.P. 28 Park-circus, Glasgow.
1908. *Bilton, Edward Barnard. Graylands, Wimbledon Common, S.W.
1887. *Bindloss, James B. Elm Bank, Buxton.
1881. ‡BINNIE, Sir ALEXANDER R., M.Inst.C.E., F.G.S. (Pres. G, 1900.) 77 Ladbroke-grove, W.
1910. *Birchenough, C., M.A. 8 Severn-road, Sheffield.
1887. *Birley, H. K. Penrhyn, Irlams-o'-th'-Height, Manchester.
1913. ‡Birtwistle, G. Pembroke College, Cambridge.
1904. ‡Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1911. *Bishop, Major C. F., R.A. The Castle, Tynemouth, Northumberland.
1906. ‡Bishop, J. L. Yarrow Lodge, Waldegrave-road, Teddington.
1910. ‡Bisset, John. Thornhill, Insch, Aberdeenshire.
1886. *Bixby, General W. H. 735 Southern-building, Washington, U.S.A.
1914. *Black, S. G. Glenormiston, Glenormiston South, Victoria.
1909. ‡Black, W. J., Principal of Manitoba Agricultural College, Winnipeg, Canada.
1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1903. *BLACKMAN, F. F., M.A., D.Sc., F.R.S. (Pres. K, 1908.) St. John's College, Cambridge.
1908. §BLACKMAN, Professor V. H., M.A., Sc.D., F.R.S. Imperial College of Science and Technology, S.W.
1913. §Blackwell, Miss Elsie M., M.Sc. 18 Stanley-avenue, Birkdale, Southport.
1913. ‡Bladen, W. Wells. Stone, Staffordshire.
1909. ‡Blaikie, Leonard, M.A. Civil Service Commission, Burlington-gardens, W.
1910. ‡Blair, R., M.A. London County Council, Spring-gardens, S.W.
1902. ‡Blake, Robert F., F.I.C. Queen's College, Belfast.
1914. §Blakemore, Mrs. D. M. Wawona, Cooper-street, Burwood, N.S.W.
1914. §Blakemore, G. H. Wawona, Cooper-street, Burwood, N.S.W.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. ‡Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, Edward J., M.A., D.Sc. Elterholm, Madingley-road, Cambridge.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1913. ‡Blofield, Rev. S., B.A. Saltley College, Birmingham.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. ‡Bloxsom, Martin, B.A., M.Inst.C.E. 4 Lansdowne-road, Crumpsall Green, Manchester.
1909. ‡Blumfield, Joseph, M.D. 35 Harley-street, W.
Blyth, B. Hall. 135 George-street, Edinburgh.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1908. ‡BOEDDICKER, OTTO, Ph.D. Birr Castle Observatory, Birr, Ireland.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1911. ‡Bolland, B. G. C. Department of Agriculture, Cairo, Egypt.
1898. §BOLTON, H., M.Sc., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §BOLTON, JOHN, F.R.G.S. Brooklyn, 87 Widmore-road, Bromley, Kent.

Year of Election.

1898. *Bonar, James, M.A., LL.D. (Pres. F, 1898 ; Council, 1899–1905.) The Mint, Ottawa, Canada.
1909. ‡Bonar, Thomson, M.D. 114 Via Babuino, Piazza di Spagna, Rome.
1912. *Bond, C. I., F.R.C.S. Springfield-road, Leicester.
1914. §Bond, Mrs. C. I. Springfield-road, Leicester.
1909. ‡Bond, J. H. R., M.B. 167 Donald-street, Winnipeg, Canada.
1908. ‡Bone, Professor W. A., D.Sc., F.R.S. Imperial College of Science and Technology, S.W.
1913. ‡*Bonnar, W., LL.B., Ph.D. Hotel Cecil, Strand, W.C.*
1871. *Bonney, Rev. Thomas George, Sc.D., LL.D., F.R.S., F.S.A., F.G.S. (President, 1910 ; Secretary, 1881–85 ; Pres. C, 1886.) 9 Scroope-terrace, Cambridge.
1911. ‡Bonny, W. Naval Store office, The Dockyard, Portsmouth.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Sir Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Right Hon. Charles, Sc.D., F.R.S., F.S.S. 28 Campden House Court, Kensington, W.
1914. §Booth, J., B.Sc. The Gables, Berkeley-street, Hawthorn, Victoria.
1883. ‡Booth, James. Hazelhurst, Turton.
1910. ‡Booth, John, M.C.E., B.Sc. The Gables, Berkeley-street, Hawthorn, Melbourne. Australia.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1901. **Boothroyd, Herbert E., M.A., B.Sc. Sidney Sussex College, Cambridge.*
1912. ‡Borgmann, Professor J. J., D.Ph., LL.D. Physical Institute, The University, Petrograd.
1882. §Borns, Henry, Ph.D. 5 Sutton Court-road, Chiswick, W.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
1903. *Bosanquet, Robert C., M.A., Professor of Classical Archæology in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool.
1896. ‡Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
1881. §Bothamley, Charles H., M.Sc., F.I.C., F.C.S., Education Secretary, Somerset County Council, Weston-super-Mare.
1871. *Bottomley, James Thomson, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. *Bottomley, W. B., M.A., Professor of Botany in King's College, W.C.
1909. ‡Boulenger, C. L., M.A., D.Sc. The University, Birmingham.
1905. §Boulenger, G. A., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W.
1905. §Boulenger, Mrs. 8 Courtfield-road, S.W.
1903. §Boulton, W. S., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1911. ‡Bourdillon, R. Balliol College, Oxford.
1883. ‡Bourne, Sir A. G., K.C.I.E., D.Sc., F.R.S., F.L.S. Middlepark, Paignton, South Devon.
1914. §Bourne, Lady. Middlepark, Paignton, South Devon.
1893. *Bourne, G. C., M.A., D.Sc., F.R.S., F.L.S. (Pres. D, 1910 ; Council, 1903–09 ; Local Sec. 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.
1904. *Bousfield, E. G. P. St. Swithin's, Hendon, N.W.
1913. §Bowater, W. H. Elm House, Arthur-road, Edgbaston, Birmingham.
1913. ‡Bowater, William. 20 Russell-road, Moseley, Birmingham.

Year of Election.

1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898, 1914; Council, 1900–06), Regius Professor of Botany in the University of Glasgow.

1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Whitehill, Wrotham, Kent.

1908. §Bowles, E. Augustus, M.A., F.L.S. Myddelton House, Waltham Cross, Herts.

1898. ‡BOWLEY, A. L., M.A. (Pres. F, 1906; Council, 1906–11.) North-court-avenue, Reading.

1880. ‡Bowly, Christopher. Cirencester.

1887. ‡Bowly, Mrs. Christopher. Cirencester.

1899. *BOWMAN, HERBERT LISTER, M.A., D.Sc., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.

1899. *Bowman, John Herbert. Greenham Common, Newbury.

1887. §Box, Alfred Marshall. 14 Magrath-avenue, Cambridge.

1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.

1892. ‡BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903; Council, 1893–99, 1905–08.) 66 Victoria-street, S.W.

1872. *BRABROOK, Sir EDWARD, C.B., F.S.A. (Pres. H, 1898; Pres. F, 1903; Council, 1903–10, 1911– .) Langham House, Wallington, Surrey.

1894. *Braby, Ivon. Helena, Alan-road, Wimbledon, S.W.

1893. §Bradley, F. L. Ingleside, Malvern Wells.

1904. *Bradley, Gustav. Council Offices, Goole.

1903. *Bradley, O. Charnock, D.Sc., M.D., F.R.S.E. Royal Veterinary College, Edinburgh.

1892. ‡Bradshaw, W. Carisbrooke House, The Park, Nottingham.

1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S. Park Hurst, Endcliffe, Sheffield.

1911. §BRAGG, W. H., M.A., F.R.S. (Council, 1913–), Professor of Physics in the University of Leeds.

1905. §Brakhan, A. 6 Montague-mansions, Portman-square, W.

1906. ‡Branfield, Wilfrid. 4 Victoria-villas, Upperthorpe, Sheffield.

1885. *Bratby, William, J.P. Alton Lodge, Lancaster Park, Harrogate.

1905 ‡Brausewetter, Miss. Roedean School, near Brighton.

1909. §Bremner, Alexander. 38 New Broad-street, E.C.

1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.

1905. ‡Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.

1913. §Brenchley, Miss Winifred E., D.Sc., F.L.S. Rothamsted Experimental Station, Harpenden, Herts.

1902. *Brereton, Cloudesley. 7 Lyndhurst-road, Hampstead, N.W.

1909. *Breton, Miss Adela C. Care of Wilts and Dorset Bank, Bath.

1905. §Brewis, E. 27 Winchelsea-road, Tottenham, N.

1908. ‡Brickwood, Sir John. Branksmere, Southsea.

1907. *Bridge, Henry Hamilton. Fairfield House, Droxford, Hants.

1912. ‡Bridgman, F. J., F.L.S. Zoological Department, University College, W.C.

1913. ‡Brierley, Leonard H. 11 Ampton-road, Edgbaston, Birmingham.

1913. §Briggs, W. Friars Croft, Park-drive, Hale, Cheshire.

1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cambridge.

1909. *Briggs, Mrs. William. Owlbrigg, Cambridge.

1908. ‡Brindley, H. H. 4 Devana-terrace, Cambridge.

1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. The Hoppet, Little Baddow, Chelmsford.

1904. ‡Briscoe, J. J. Bourn Hall, Bourn, Cambridge.

Year of Election.

1905. §Briscoe, Miss. Bourn Hall, Bourn, Cambridge.
1898. ‡BRISTOL, The Right Rev. G. F. BROWNE, D.D., Lord Bishop of. 17 The Avenue, Clifton, Bristol.
1879. *BRITTAIN, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1905. **Broadwood, Brigadier-General R. G. The Deodars, Bloemfontein, South Africa.*
1905. ‡Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
1907. ‡Brockington, W. A., M.A. Birstall, Leicester.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1901. ‡Brodie, T. G., M.D., F.R.S., Professor of Physiology in the University of Toronto. The University, Toronto, Canada.
1883. *Brodie-Hall, Miss W. L. Havenwood, Peaslake, Gomshall, Surrey.
1903. ‡BRODRICK, HAROLD, M.A., F.G.S. (Local Sec. 1903.) 7 Aughton-road, Birkdale, Southport.
1913. ‡Brodrick, Mrs. Harold. 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'A., M.A., F.R.S. 1 Selwyn-gardens, Cambridge.
1906. ‡Brook, Stanley. 18 St. George's-place, York.
1911. §Brooke, Colonel Charles K., F.R.G.S. Army and Navy Club, Pall Mall, S.W.
1906. *Brooks, F. T. 31 Tenison-avenue, Cambridge.
1883. *Brough, Mrs. Charles S. 4 Spencer-road, Southsea.
1886. ‡Brough, Joseph, LL.D., Professor of Logic and Philosophy in University College, Aberystwyth.
1913. §Brown, Professor A. J., M.Sc., F.R.S. West Heath House, Northfield, Birmingham.
1905. ‡Brown, A. R. Trinity College, Cambridge.
1863. *BROWN, ALEXANDER CRUM, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871.) 8 Belgrave-crescent, Edinburgh.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1905. §Brown, Professor Ernest William, M.A., D.Sc., F.R.S. Yale University, New Haven, Conn., U.S.A.
1914. §Brown, F. G., B.A., B.Sc. Naval College, North Geelong, Victoria.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1914. §Brown, Rev. George, D.D. Kinawanua, Gordon, N.S.W.
1870. §BROWN, HORACE T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904–11.) 52 Nevern-square, S.W.
1881. *Brown, John, M.D. Rosebank, Cape of Good Hope.
1895. *Brown, John Charles. 39 Burlington-road, Sherwood, Nottingham.
1882. *Brown, Mrs. Mary. Rosebank, Cape of Good Hope.
1901. ‡Brown, Professor R. N. Rudmose, D.Sc. The University, Sheffield.
1908. §BROWN, SIDNEY G. 52 Kensington Park-road, W.
1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W.
1910. *Brown, Sidney J. R. 52 Kensington Park-road, W.
1912. ‡Brown, T. Graham. The University, Liverpool.
1884. ‡Brown, W. G. University of Missouri, Columbia, Missouri, U.S.A.
1908. ‡Brown, William, B.Sc. 48 Dartmouth-square, Dublin.
1912. ‡Brown, Dr. William. Thornfield, Horley, Surrey.
1906. ‡Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.
1900. *BROWNE, FRANK BALFOUR, M.A., F.R.S.E., F.Z.S. 26 Barton-road, Cambridge.
1908. ‡Browne, Rev. Henry, M.A., Professor of Greek in University College, Dublin.
1895. *Browne, H. T. Doughty. 6 Kensington House, Kensington-court, W.

Year of Election.

1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 41 Hans-place, S.W.
1905. *Browne, James Stark, F.R.A.S. Hillcrest, Castlebar-hill, Ealing, W.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1912. §Browning, T. B., M.A. 19 Aldermary-road, Bromley, Kent.
1905. §BRUCE, Colonel Sir DAVID, C.B., F.R.S., A.M.S. (Pres. I, 1905.) Royal Society Commission, Kasu Hill (near Mvera), Central Angoniland, Nyasaland Protectorate, British Central Africa.
1905. ‡Bruce, Lady. 3P Artillery-mansions, Victoria-street, S.W.
1893. ‡BRUCE, WILLIAM S., LL.D., F.R.S.E. Scottish Oceanographical Laboratory, Surgeons' Hall, Edinburgh.
1902. ‡*Bruce-Kingsmill, Major J., F.C.S. 4 St. Ann's-square, Manchester.*
1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1896. *Brunner, Right Hon. Sir J. T., Bart. Silverlands, Chertsey.
1868. ‡BRUNTON, Sir T. LAUDER, Bart., M.D., Sc.D., F.R.S. (Council, 1908–12.) 10 Stratford-place, Cavendish-square, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1886. *BRYAN, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. *BRYCE, Rev. Professor GEORGE, D.D., LL.D. Kilmadock, Winnipeg, Canada.
1909. ‡Bryce, Thomas H., M.D., Professor of Anatomy in the University of Glasgow. 2 The College, Glasgow.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1902. *BUCHANAN, Miss FLORENCE, D.Sc. University Museum, Oxford.
1905. ‡Buchanan, Hon. Sir John. Clareinch, Claremont, Cape Town.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 26 Norfolk-street, Park-lane, W.
1909. ‡Buchanan, W. W. P.O. Box 1658, Winnipeg, Canada.
1914. §Buck, E. J. Menzies' Hotel, Melbourne.
1913. ‡Buckland, H. T. 21 Yateley-road, Edgbaston, Birmingham.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1904. ‡Buckwell, J. C. North Gate House, Pavilion, Brighton.
1893. §BULLEID, ARTHUR, F.S.A. Dymboro, Midsomer Norton, Bath.
1913. *Bulleid, C. H. University College, Nottingham.
1913. *Buller, A. H. Reginald, Professor of Botany in the University of Manitoba, Winnipeg.
1909. ‡BULYEA, The Hon. G. H. V. Edmonton, Alberta, Canada.
1914. §Bundey, Miss E. M. Molesworth-street, North Adelaide, South Australia.
1905. ‡Burbury, Mrs. A. A. 15 Melbury-road, W.
1905. ‡Burbury, Miss A. D. 15 Melbury-road, W.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. ‡BURDON, E. R., M.A. Ikenhilde, Royston, Herts.
1913. §Burfield, Stanley Thomas. Zoology Department, The University, Liverpool.
1913. *Burgess, J. Howard. Shide, Newport, Isle of Wight.
1894. ‡BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, Montreal, Canada.
1899. ‡Burls, H. T., F.G.S. 2 Verulam-buildings, Gray's Inn, W.C.

Year of Election.

1904. ‡Burn, R. H. 21 Stanley-crescent, Notting-hill, W.
1914. *Burns, Colonel James. Gowan Brae, Parramatta, N.S.W.
1909. ‡Burns, F. D. 203 Morley-avenue, Winnipeg, Canada.
1908. ‡Burnside, W. Snow, D.Sc., Professor of Mathematics in the University of Dublin. 35 Raglan-road, Dublin.
1905. ‡Burroughes, James S., F.R.G.S. The Homestead, Seaford, Sussex.
1909. ‡Burrows, Theodore Arthur. 187 Kennedy-street, Winnipeg, Canada.
1910. ‡Burt, Cyril. The University, Liverpool.
1894. ‡Burton, C. V. Boar's Hill, Oxford.
1909. ‡Burton, E. F. 129 Howland-avenue, Toronto, Canada.
1911. ‡Burton, J. H. County Education Office, Weston-super-Mare.
1892. ‡Burton-Brown, Colonel A., F.G.S. Royal Societies Club, St. James's-street, S.W.
1904. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. ‡Burtt, Philip. Swarthmore, St. George's-place, York.
1909. ‡Burwash, E. M., M.A. New Westminster, British Columbia, Canada.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. ‡Bush, Anthony. 43 Portland-road, Nottingham.
1895. ‡Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1908. *Bushell, W. F. Rossall School, Fleetwood.
1910. ‡Butcher, Miss. 25 Earl's Court-square, S.W.
1884 *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1913. *Butler, W. Waters. Southfield, Norfolk-road, Edgbaston, Birmingham.
1884. *Butterworth, W. Carisbrooke, Rhin-road, Colwyn Bay, North Wales.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1913. §Cadbury, Edward. Westholme, Selly Oak, Birmingham.
1913. ‡Cadbury, W. A. Wast Hills, King's Norton.
1892. ‡Cadell, H. M., B.Sc., F.R.S.E. Grange, Linlithgow.
1908. ‡Cadic, Edouard, D.Litt. Mon Caprice, Pembroke Park, Dublin.
1913. ‡Cadman, John, D.Sc., Professor of Mining in the University of Birmingham. 61 Wellington-road, Edgbaston, Birmingham.
1913. ‡Cadman, W. H., B.Sc. Matarieh, Cairo, Egypt.
1913. ‡Cahill, J. R. 49 Hanover Gate-mansions, Regent's Park, N.W.
1912. §Caine, Nathaniel. Spital, Cheshire.
1861. *Caird, Sir James Key, Bart., LL.D. 8 Magdalen Yard-road, Dundee.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1907. ‡Caldwell, K. S. St. Bartholomew's Hospital, S.E.
1897. ‡Callendar, Hugh L., M.A., LL.D., F.R.S. (Pres. A, 1912; Council, 1900–06), Professor of Physics in the Imperial College of Science and Technology, S.W.
1911. ‡Calman, W. T., D.Sc. British Museum (Natural History), Cromwell-road, S.W.
1911. ‡Cameron, Alexander T. Physiological Department, University of Manitoba, Winnipeg.
1857. ‡Cameron, Sir Charles A., C.B., M.D. 51 Pembroke-road, Dublin.
1909. ‡Cameron, D. C. 65 Roslyn-road, Winnipeg, Canada.
1896. §Cameron, Irving H., LL.D., Professor of Surgery in the University of Toronto. 307 Sherbourne-street, Toronto, Canada.

Year of Election.

1909. ‡Cameron, Hon. Mr. Justice J. D. Judges' Chambers, Winnipeg, Canada.
1901. §Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1909. *Campbell, R. J. Holdenhurst, Hendon-avenue, Church End, Finchley, N.
1909. ‡Campbell, Mrs. R. J. Holdenhurst, Hendon-avenue, Church End, Finchley, N.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1912. ‡Campbell, Dr. Robert. Geological Department, The University, Edinburgh.
1890. ‡CANNAN, Professor EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 11 Chadlington-road, Oxford.
1905. ‡Cannan, Gilbert. King's College, Cambridge.
1897. §Cannon, Herbert. Alconbury, Bexley Heath, Kent.
1904. ‡Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1911. ‡Capon, R. S. 49A Rodney-street, Liverpool.
1905. *Caporn, Dr. A. W. Muizenberg, South Africa.
1894. ‡CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1887. ‡CAPSTICK, J. W. Trinity College, Cambridge.
1896. *Carden, H. Vandeleur. Fir Lodge, Broomfield, Chelmsford.
1913. ‡Carlier, E. Wace, M.Sc., M.D., F.R.S.E., Professor of Physiology in the University of Birmingham. The University, Edmund-street, Birmingham.
1914. §Carne, J. E. Mines Department, Sydney, N.S.W.
1913. §Carpenter, Charles. 157 Victoria-street, S.W.
1913. *Carpenter, G. D. H., M.B. 19 Bardwell-road, Oxford.
1902. ‡Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, H. C. H. 30 Murray-road, Wimbledon.
1905. §Carpmael, Edward, F.R.A.S., M.Inst.C.E. 24 Southampton-buildings, Chancery-lane, W.C.
1912. *Carr, H. Wildon, D.Litt. 10 More's Garden, Cheyne-walk, S.W.
1910. ‡Carr, Henry F. Broadparks, Pinhoe, near Exeter.
1893. ‡CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1906. *Carr, Richard E. Sylvan Mount, Sylvan-road, Upper Norwood, S.E.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1911. ‡Carruthers, R. G., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 44 Central-hill, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM. (Local Sec. 1886.) 30 Westfield-road, Birmingham.
1899. §CARSLAW, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1914. §Carson, Rev. James. The Manse, Cowper, N.S.W.
1911. ‡Carter, Godfrey, M.B. 4 Lawson-road, Broomhill, Sheffield.
1900. *CARTER, W. LOWER, M.A., F.G.S. Bolbec, Grange Road, Watford.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. 21 Parsons-lane, Bury, Lancashire.

Year of Election.

1862. ‡Carulla, F. J. R. 84 Rosehill-street, Derby.
1894. ‡Carus, Dr. Paul. La Salle, Illinois, U.S.A.
1913. §Carus-Wilson, Cecil, F.R.S.E., F.G.S. Altmore, Waldegrave-park, Strawberry Hill, Twickenham.
1901. ‡Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 9 Springfield-road, Dalmarnock, Glasgow.
1899. *Case, J. Monckton. Department of Lands (Water Branch), Victoria, British Columbia.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1908. *Cave, Charles J. P., M.A. Ditcham Park, Petersfield.
1910. ‡Chadburn, A. W. Brincliffe Rise, Sheffield.
1905. *Challenor, Bromley, M.A. The Firs, Abingdon.
1905. *Challenor, Miss E. M. The Firs, Abingdon.
1910. §Chalmers, Stephen D. 25 Cornwall-road, Stroud Green, N.
1913. ‡Chalmers, Mrs. S. D. 25 Cornwall-road, Stroud Green, N.
1913. ‡CHAMBERLAIN, NEVILLE. Westbourne, Edgbaston, Birmingham.
1914. §Chamberlin, Dr. R. T. Geological Department, University of Chicago, U.S.A.
1913. ‡Chambers, Miss Beatrice Anne. Glyn-y-mêl, Fishguard.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff.
1905. ‡Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal.
1881. *Champney, John E. 27 Hans-place, S.W.
1908. ‡Chance, Sir Arthur, M.D. 90 Merrion-square, Dublin.
1888. ‡Chandler, S. Whitty, B.A. St. George's, Cecil-road, Boscombe.
1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C.
1902. *Chapman, D. L., F.R.S. Jesus College, Oxford.
1914. §Chapman, H. G., M.D. Department of Physiology, The University, Sydney, N.S.W.
1910. ‡Chapman, J. E. Kinross.
1899. §CHAPMAN, Professor SYDNEY JOHN, M.A., M.Com. (Pres. F, 1909.) Burnage Lodge, Levenshulme, Manchester.
1912. *Chapman, Sydney, D.Sc., B.A., F.R.A.S. Royal Observatory, Greenwich, S.E.
1910. ‡Chappell, Cyril. 73 Neill-road, Sheffield.
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. 151 Woodstock-road, Oxford.
1886. *CHATTOCK, A. P., D.Sc. Heathfield Cottage, Crowcombe, Somerset.
1904. *Chaundy, Theodore William, M.A. Christ Church, Oxford.
1913. §Cheesman, Miss Gertrude Mary. The Crescent, Selby.
1900. *Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Lieut.-General Sir Herbert, R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1908. ‡Cherry, Right Hon. Lord Justice. 92 St. Stephen's Green, Dublin.
1910. ‡Chesney, Miss Lilian M., M.B. 381 Glossop-road, Sheffield.
1879. *Chesterman, W. Belmayne, Sheffield.
1911. *Chick, Miss H., D.Sc. Chestergate, Park-hill, Ealing, W.
1908. ‡Chill, Edwin, M.D. Westleigh, Mattock-road, Ealing, W.
1883. ‡Chinery, Edward F., J.P. Lymington.
1894. ‡CHISHOLM, G. G., M.A., B.Sc., F.R.G.S. (Pres. E, 1907.) 12 Hallhead-road, Edinburgh.
1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. ‡Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1904. §Chivers, John, J.P. Wychfield, Cambridge.
1882. ‡Chorley, George. Midhurst, Sussex.

Year of Election.

1909. ‡Chow, H. H., M.D. 263 Broadway, Winnipeg, Canada.
1893. *CHREE, CHARLES, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1913. §Christie, Dr. M. G. Post Office House, Leeds.
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George, F.C.S. Thorncroft, Chislehurst.
1870. §CHURCH, Sir ARTHUR, K.C.V.O., M.A., F.R.S., F.S.A. Shelsley, Ennerdale-road, Kew.
1903. ‡Clapham, J. H., M.A. King's College, Cambridge.
1901. §Clark, Archibald B., M.A., Professor of Political Economy in the University of Manitoba, Winnipeg, Canada.
1905. *Clark, Cumberland, F.R.G.S. 22 Kensington Park-gardens, W.
1907. *Clark, Mrs. Cumberland. 22 Kensington Park-gardens, W.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. South African Museum, Cape Town.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road, Purley, Surrey.
1909. ‡Clark, J. M., M.A., K.C. The Kent Building, 156 Yonge-street, Toronto, Canada.
1908. ‡Clark, James, B.Sc., Ph.D. Newtown School, Waterford, Ireland.
1908. §Clark, John R. W. Brothock Bank House, Arbroath, Scotland.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.
1907. *Clarke, E. Russell. 11 King's Bench-walk, Temple, E.C.
1902. *CLARKE, Miss LILIAN J., B.Sc., F.L.S. Chartfield Cottage, Brasted Chart, Kent.
1889. *CLAYDEN, A. W., M.A., F.G.S. 5 The Crescent, Mount Radford, Exeter.
1908. *Clayton, Miss Edith M. Brackendene, Horsell, Surrey.
1909. §Cleeves, Frederick, F.Z.S. 23 Lime-street, E.C.
1909. ‡Cleeves, W. B. Public Works Department, Government-buildings, Pretoria.
1861. ‡CLELAND, JOHN, M.D., D.Sc., F.R.S. Drumclog, Crewkerne, Somerset.
1905. §Cleland, Mrs. Drumclog, Crewkerne, Somerset.
1905. §Cleland, Lieutenant J. R. Drumclog, Crewkerne, Somerset.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §CLERK, Dr. DUGALD, F.R.S., M.Inst.C.E. (Pres. G, 1908; Council 1912- .) 57 and 58 Lincoln's Inn Fields, W.C.
1909. ‡Cleve, Miss E. K. P. 74 Kensington Gardens-square, W.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1906. §CLOSE, Colonel C. F., R.E., C.M.G., F.R.G.S. (Pres. E, 1911; Council, 1908-12.) Ordnance Survey Office, Southampton.
1914. §Close, J. Campbell. 217 Clarence-street, Sydney, N.S.W.
1883. *CLOWES, Professor FRANK, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E.
1914. §Clowes, Mrs. The Grange, College-road, Dulwich, S.E.
1912. §Clubb, Joseph A., D.Sc. Free Public Museum, Liverpool.
1891. *Coates, Henry, F.R.S.E. Balure, Perth.
1884. ‡Cobb, John. Fitzharris, Abingdon.
1911. §Cobbold, E. S., F.G.S. Church Stretton, Shropshire.
1908. *Cochrane, Miss Constance. The Downs, St. Neots.
1908. ‡Cochrane, Robert, I.S.O., LL.D., F.S.A. 17 Highfield-road, Dublin.
1901. ‡Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone-road, Upper Norwood, S.E.

Year of Election.

1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1913. ‡Codd, J. Alfred. 7 Tettenhall-road, Wolverhampton.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1908. ‡*Coffey, Denis J., M.B. 2 Arkendale-road, Glenageary, Co. Dublin.*
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *Coffin, Walter Harris, F.C.S. National Liberal Club, S.W.
1896. *Coghill, Percy de G. Sunnyside House, Prince's Park, Liverpool.
1914. §Coghill, Mrs. Una. Monomeath-avenue, Canterbury, Victoria.
1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W.
1906. *Coker, Ernest George, M.A., D.Sc., F.R.S.E. (Pres. G, 1914), Professor of Civil and Mechanical Engineering, University College, Gower-street, W.C.
1914. §Coker, Mrs. 3 Farnley-road, Chingford, Essex.
1895. *Colby, William Henry. Cairn Villa, St. Brannock's-road, Ilfracombe.
1913. §Cole, Professor F. J. University College, Reading.
1893. §Cole, Grenville A. J., F.G.S., Professor of Geology in the Royal College of Science, Dublin.
1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1910. §Cole, Thomas Skelton. Westbury, Endcliffe-crescent, Sheffield.
1897. §Coleman, Professor A. P., M.A., Ph.D., F.R.S. (Pres. C, 1910.) 476 Huron-street, Toronto, Canada.
1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1912. ‡Collett, J. M., J.P. Kimsbury House, Gloucester.
1887. ‡Collie, J. Norman, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1913. ‡Collinge, Walter E., M.Sc. 8 Newhall-street, Birmingham.
1861. *Collingwood, J. Frederick, F.G.S. 8 Oakley-road, Canonbury, N.
1876. ‡Collins, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1910. *Collins, S. Hoare. 9 Cavendish-place, Newcastle-on-Tyne.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1914. §Collum, Mrs. Anna Maria. 18 Northbrook-road, Leeson Park, Dublin.
1892. ‡Colman, Dr. Harold G. 1 Arundel-street, Strand, W.C.
1910. *Colver, Robert, jun. Graham-road, Ranmoor, Sheffield.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1910. *Compton, Robert Harold, B.A. Gonville and Caius College, Cambridge.
1912. §Conner, Dr. William. The Priory, Waterlooville, Hants.
1902. ‡Conway, A. W. 100 Leinster-road, Rathmines, Dublin.
1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. §Cook, Ernest H., D.Sc. 27 Berkeley-square, Clifton, Bristol.
1913. §Cook, Gilbert, M.Sc., Assoc.M.Inst.C.E. Engineering Department, The University, Manchester.
1876. *Cooke, Conrad W. The Pines, Langland-gardens, Hampstead, N.W.
1911. ‡Cooke, J. H. 101 Victoria-road North, Southsea.
1914. §Cooke, William Ternant, D.Sc. Fourth-avenue, East Adelaide, South Australia.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.

Year of
Election.

1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1911. §Cooper, W. E. Henwick Lodge, Worcester.
1912. §Cooper, W. F. The Laboratory, Rickmansworth-road, Watford.
1907. ‡Cooper, William. Education Offices, Becket-street, Derby.
1904. *COPEMAN, S. MONCKTON, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1909. §Copland, Mrs. A. J. Gleniffer, 50 Woodberry Down, N.
1904. *Copland, Miss Louisa. 10 Wynnstay-gardens, Kensington, W.
1909. ‡Corbett, W. A. 207 Bank of Nova Scotia-building, Winnipeg, Canada.
1887. *Corcoran, Bryan. 43 Croham Park-avenue, South Croydon.
1894. §Corcoran, Miss Jessie R. Rotherfield Cottage, Bexhill-on-Sea.
1901. *Cormack, J. D., D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡CORNISH, VAUGHAN, D.Sc., F.R.G.S. Woodville, Camberley.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
1900. §CORTIE, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. ‡Cory, Professor G. E., M.A. Rhodes University College, Grahamstown, Cape Colony.
1909. *Cossar, G. C., M.A., F.G.S. Southview, Murrayfield, Edinburgh.
1910. §Cossar, James. 28 Coltbridge-terrace, Murrayfield, Midlothian.
1911. ‡Cossey, Miss, M.A. High School for Girls, Kent-road, Southsea.
1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh, Ireland.
1874. *COTTERILL, J. H., M.A., F.R.S. Hillcrest, Parkstone, Dorset.
1908. ‡Cotton, Alderman W. F., D.L., J.P., M.P. Hollywood, Co. Dublin.
1908. ‡Courtenay, Colonel Arthur H., C.B., D.L. United Service Club, Dublin.
1896. ‡COURTNEY, Right Hon. Lord. (Pres. F, 1896.) 15 Cheyne-walk, Chelsea, S.W.
1911. ‡Couzens, Sir G. E., K.L.H. Glenthorne, Kingston-crescent, Portsmouth.
1908. ‡Cowan, P. C., B.Sc., M.Inst.C.E. 33 Ailesbury-road, Dublin.
1872. *Cowan, Thomas William, F.L.S., F.G.S. Upcott House, Taunton, Somersetshire.
1903. ‡Coward, H. Knowle Board School, Bristol.
1900. §Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1914. §Cowburn, Mrs. Dingle Head, Leigh, Lancashire.
1895. *COWELL, PHILIP H., M.A., D.Sc., F.R.S. 62 Shooters Hill-road, Blackheath, S.E.
1899. ‡Cowper-Coles, Sherard. 1 and 2 Old Pye-street, Westminster, S.W.
1913. ‡Cox, A. Hubert. King's College, Strand, W.C.
1909. ‡Cox, F. J. C. Anderson-avenue, Winnipeg, Canada.
1906. ‡*Cox, S. Herbert, Professor of Mining in the Imperial College of Science and Technology, S.W.*
1905. ‡Cox, W. H. Royal Observatory, Cape Town.
1912. ‡Craig, D. D., M.A., B.Sc., M.B. The University, St. Andrews, N.B.
1908. ‡Craig, James, M.D. 18 Merrion-square North, Dublin.
1911. §Craig, J. I. Homelands, Park-avenue, Worthing.
1884. §CRAIGIE, Major P. G., C.B., F.S.S. (Pres. F, 1900; Council, 1908– .) Bronté House, Lympstone, Devon.
1906. ‡Craik, Sir Henry, K.C.B., LL.D., M.P. 5A Dean's-yard, Westminster, S.W.

Year of Election.

1908. *Cramer, W., Ph.D., D.Sc. Physiological Department, The University, Edinburgh.
1906. ‡*Cramp, William. Redthorn, Whalley-road, Manchester.*
1905. *Cranswick, W. F. P.O. Box 65, Bulawayo, Rhodesia.
1906. ‡Craven, Henry. (Local Sec. 1906.) Greenbank, West Lawn, Sunderland.
1905. ‡Crawford, Mrs. A. M. Marchmont, Rosebank, near Cape Town.
1910. *Crawford, O. G. S. The Grove, East Woodhay, Newbury.
1905. ‡Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E. South African College, Cape Town.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1905. ‡Crawford, W. C., jun. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1885. §Creak, Captain E. W., C.B., R.N., F.R.S. (Pres. E, 1903; Council, 1896–1903.) 9 Hervey-road, Blackheath, S.E.
1876. *Crewdson, Rev. Canon George. Whitstead, Barton-road, Cambridge.
1887. *Crewdson, Theodore. Spurs, Styall, Handforth, Manchester.
1911. ‡Crick, George C., F.G.S. British Museum (Natural History), S.W.
1904. ‡Crilly, David. 7 Well-street, Paisley.
1880. *Crisp, Sir Frank, Bart., B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1908. §Crocker, J. Meadmore. Albion House, Bingley, Yorkshire.
1905. §Croft, Miss Mary. Quedley, Shottermill.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. *Croke, John O'Byrne, M.A. Clouncagh, Ballingarry-Lacy, Co. Limerick.
1913. §Crombie, J. E. Parkhill House, Dyce, Aberdeenshire.
1903. *Crompton, Holland. Oaklyn, Cross Oak-road, Berkhamsted.
1901. ‡Crompton, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington-court, W.
1887. ‡Crook, Henry T., M.Inst.C.E Lancaster-avenue, Manchester.
1898. §Crooke, William, B.A. (Pres. H, 1910; Council, 1910– .) Langton House, Charlton Kings, Cheltenham.
1865. §Crookes, Sir William, O.M., D.Sc., Pres.R.S., V.P.C.S. (President, 1898; Pres. B, 1886; Council, 1885–91.) 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *Crookshank, E. M., M.B. Saint Hill, East Grinstead, Sussex.
1909. ‡Crosby, Rev. E. H. Lewis, B.D. 36 Rutland-square, Dublin.
1905. ‡Crosfield, Hugh T. Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1890. ‡*Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.*
1905. §Cross, Robert. 13 Moray-place, Edinburgh.
1904. *Crossley, A. W., D.Sc., Ph.D., F.R.S. 46 Windfield-gardens, Hampstead, N.W.
1908. ‡Crossley, F. W. 30 Molesworth-street, Dublin.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1890. *Crowley, Ralph Henry, M.D. Sollershott W., Letchworth.
1910. ‡Crowther, Dr. C., M.A. The University, Leeds.
1910. *Crowther, James Arnold. St. John's College, Cambridge.

Year of Election.

1911. §Crush, S. T. Care of Messrs. Yarrow & Co., Ltd., Scotstoun West, Glasgow.

1883. *CULVERWELL, EDWARD P., M.A., Professor of Education in Trinity College, Dublin.

1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.

1914. *Cuming, James. 65 William-street, Melbourne.

1914. *Cuming, W. Fehon. Hyde-street, Yarraville, Victoria.

1911. ‡Cumming, Alexander Charles, D.Sc. Chemistry Department, University of Edinburgh.

1911. §CUMMINS, Major H. A., M.D., C.M.G., Professor of Botany in University College, Cork.

1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.

1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.

1905. ‡Cunningham, Miss A. 2 St. Paul's-road, Cambridge.

1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.

1905. ‡Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa.

1911. ‡Cunningham, E. St. John's College, Cambridge.

1885. ‡CUNNINGHAM, J. T., M.A. 63 St. Mary's-grove, Chiswick, W.

1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.

1883. *CUNNINGHAM, Ven. W., D.D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.

1900. *Cunnington, William A., M.A., Ph.D., F.Z.S. 25 Orlando-road, Clapham Common, S.W.

1912. §CUNYNGHAME, Sir HENRY H., K.C.B. (Pres. F, 1912.) 15 The Leas, Folkestone.

1914. §Cunynghame, Lady. 15 The Leas, Folkestone.

1914. §Curdie, Miss Jessie. Camperdown, Victoria.

1913. ‡Currall, A. E. Streetsbrook-road, Solihull, Birmingham.

1908. ‡Currelly, C. T., M.A., F.R.G.S. United Empire Club, 117 Piccadilly, W.

1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.

1905. ‡Currie, Dr. O. J. Manor House, Mowbray, Cape Town.

1905. ‡Currie, W. P. P.O. Box 2010, Johannesburg.

1902. ‡Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.

1912. §Curtis, Charles. Field House, Cainscross, Stroud, Gloucestershire.

1907. ‡CUSHNY, ARTHUR R., M.D., F.R.S., Professor of Pharmacology in University College, Gower-street, W.C.

1913. ‡Cutler, A. E. 5 Charlotte-road, Edgbaston, Birmingham.

1913. ‡Czaplicka, Miss M. A. Somerford College, Oxford.

1910. ‡DAKIN, Dr. W. J., Professor of Biology in the University of Western Australia, Perth, Western Australia.

1914. §Dakin, Mrs. University of Western Australia, Perth, Western Australia.

1898. *DALBY, W. E., M.A., B.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1910), Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.

1889. *Dale, Miss Elizabeth. Garth Cottage, Oxford-road, Cambridge.

1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.

1907. ‡DALGLIESH, RICHARD, J.P., D.L. Ashfordby Place, near Melton Mowbray.

Year of Election.

1904. *Dalton, J. H. C., M.D. The Plot, Adams-road, Cambridge.
1862. ‡Danby, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1905. ‡Daniel, Miss A. M. 3 St. John's-terrace, Weston-super-Mare.
1901. *Daniell, G. F., B.Sc. Woodberry, Oakleigh Park, N.
1914. §Danks, A. T. 391 Bourke-street, Melbourne.
1896. §Danson, F. C. Tower-buildings, Water-street, Liverpool.
1897. ‡Darbishire, F. V., B.A., Ph.D. Dorotheenstrasse 12, Dresden 20.
1903. ‡Darbishire, Dr. Otto V. The University, Bristol.
1905. ‡Darwin, Lady. Newnham Grange, Cambridge.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. *Darwin, Sir Francis, M.A., M.B., LL.D., D.Sc., F.R.S., F.L.S. (President, 1908; Pres. D, 1891; Pres. K, 1904; Council, 1882–84, 1897–1901.) 10 Madingley-road, Cambridge.
1878. *Darwin, Horace, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *Darwin, Major Leonard, F.R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W.
1910. ‡Dauncey, Mrs. Thursby. Lady Stewert, Heath-road, Weybridge.
1908. ‡*Davey, H. 15 Victoria-road, Brighton.*
1880. *Davey, Henry, M.Inst.C.E. Conaways, Ewell, Surrey.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1914. §David, Professor T. W. Edgeworth, C.M.G., D.Sc., F.R.S. The University, Sydney, N.S.W.
1904. ‡Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1913. §Davidge, W. R., A.M.Inst.C.E. Bank House, Lewisham, S.E.
1913. §Davidge, Mrs. Bank House, Lewisham, S.E.
1909. ‡Davidson, A. R. 150 Stradbrooke-place, Winnipeg, Canada.
1912. ‡Davidson, Rev. J. The Manse, Douglas, Isle of Man.
1912. ‡Davidson, John, M.A., D.Ph. Training College, Small's Wynd, Dundee.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1914. §Davidson, W. R. 15 Third-avenue, Hove.
1910. *Davie, Robert C., M.A., B.Sc. Royal Botanic Garden, Edinburgh.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N., F.G.S. St. Chad's, Weston-super-Mare.
1906. ‡Davies, S. H. Ryecroft, New Earswick, York.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., D.D., Professor of Semitic Languages in University College, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1873. *Davis, Alfred. 37 Ladbroke-grove, W.
1896. *Davis, John Henry Grant. Dolobran, Wood Green, Wednesbury.
1910. ‡Davis, Captain John King. 9 Regent-street, W.
1905. ‡Davis, Luther. P.O. Box 898, Johannesburg.
1885. *Davis, Rev. Rudolf. Mornington, Elmbridge-road, Gloucester.
1905. ‡Davy, Joseph Burtt, F.R.G.S., F.L.S. Care of Messrs. Dulau & Co., 37 Soho-square, W.
1912. ‡Dawkins, Miss Ella Boyd. Fallowfield House, Fallowfield, Manchester.
1864. ‡Dawkins, W. Boyd, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88.) Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.

Year of Election.

1905. ‡Dawson, Mrs. The Acre, Maryhill, Glasgow.
1912. *Dawson, Shepherd, M.A., B.Sc. Drumchapel, near Glasgow.
1906. §Dawson, William Clarke. Whitefriargate, Hull.
1859. *Dawson, Captain W. G. Abbots Morton, near Worcester.
1900. ‡Deacon, M. Whittington House, near Chesterfield.
1909. §Dean, George, F.R.G.S. 14 Evelyn-mansions, Queen's Club-gardens, W.
1901. *Deasy, Captain H. H. P. Cavalry Club, 127 Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1914. §Debenham, Frank. Caius College, Cambridge.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. (Pres. B, 1869; Council, 1870–75.) 4 Schlangenweg, Cassel, Hessen.
1893. *Deeley, R. M., M.Inst.C.E., F.G.S. Abbeyfield, Salisbury-avenue Harpenden, Herts.
1911. ‡Delahunt, C. G. The Municipal College, Portsmouth.
1878. ‡DELANY, Very Rev. WILLIAM, LL.D. University College, Dublin.
1908. *Delf, Miss E. M. Westfield College, Hampstead, N.W.
1914. §Delprat, G. L. Equitable-building, Collins-street. Melbourne.
1907. ‡*De Lisle, Mrs. Edwin. Charnwood Lodge, Coalville, Leicestershire.*
1896. ‡Dempster, John. Tynron, Noctorum, Birkenhead.
1902. *DENDY, ARTHUR, D.Sc., F.R.S., F.L.S. (Pres. D, 1914; Council, 1912–), Professor of Zoology in King's College, London, W.C.
1914. §Dendy, Miss. Vale Lodge, Hampstead, N.W.
1913. *Denman, Thomas Hercy. 17 Churchgate, Retford, Nottinghamshire.
1908. ‡Dennehy, W. F. 23 Leeson-park, Dublin.
1889. §DENNY, ALFRED, M.Sc., F.L.S., Professor of Zoology in the University of Sheffield. Cliffside, Ranmoor-crescent, Sheffield.
1914. §Denny, Mrs. Cliffside, Ranmoor-crescent, Sheffield.
1909. §Dent, Edward, M.A. 2 Carlos-place, W.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Junior Carlton Club, Pall Mall, S.W.
1907. *Desch, Cecil H., D.Sc., Ph.D. 3 Kelvinside-terrace North, Glasgow.
1908. ‡Despard, Miss Kathleen M. 6 Sutton Court-mansions, Grove Park-terrace, Chiswick, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1868. *DEWAR, Sir JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (PRESIDENT, 1902; Pres. B, 1879; Council, 1883–88.) 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Lady. 1 Scroope-terrace, Cambridge.
1884. *Dewar, William, M.A. Horton House, Rugby.
1914. §Dickinson, Miss Desiree. Menzies' Hotel, Melbourne.
1908. §Dicks, Henry. Haslecourt, Horsell, Woking.
1904. ‡Dickson, Right Hon. Charles Scott, K.C., LL.D., M.P. Carlton Club, Pall Mall, S.W.
1881. ‡Dickson, Edmund, M.A., F.G.S. Claughton House, Garstang, R.S.O., Lancashire.
1887. §DICKSON, H. N., D.Sc., F.R.S.E., F.R.G.S. (Pres. E, 1913), Professor of Geography in University College, Reading. 160 Castle-hill, Reading.
1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.

Year of Election.

1913. *Dickson, T. W. 60 Jeffrey's-road, Clapham, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1908. ‡Dines, J. S. Pyrton Hill, Watlington.
1901. §Dines, W. H., B.A., F.R.S. Benson, Wallingford, Berks.
1905. §DIXEY, F. A., M.A., M.D., F.R.S. (Council, 1913- .) Wadham College, Oxford.
1899. *DIXON, A. C., D.Sc., F.R.S., Professor of Mathematics in Queen's University, Belfast. Hurstwood, Malone Park, Belfast.
1874. *DIXON, A. E., M.D., Professor of Chemistry in University College, Cork.
1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1905. ‡Dixon, Miss E. K. Fern Bank, St. Bees, Cumberland.
1908. ‡Dixon, Edward K., M.E., M.Inst.C.E. Castlebar, Co. Mayo.
1888. ‡Dixon, Edward T. Racketts, Hythe, Hampshire.
1908. *DIXON, ERNEST, B.Sc., F.G.S. The Museum, Jermyn-street, S.W.
1900. *Dixon, Lieut.-Colonel George, M.A. Fern Bank, St. Bees, Cumberland.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S. (Pres. B, 1894; Council 1913-), Professor of Chemistry in the Victoria University, Manchester.
1914. §Dixon, Mrs. H. B., Beechey House, Wilbraham-road, Fallowfield, Manchester.
1902. ‡DIXON, HENRY H., D.Sc., F.R.S., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1913. ‡Dixon, S. M., M.A., M.Inst.C.E., Professor of Civil Engineering in the Imperial College of Science and Technology, London, S.W.
1908. *Dixon, Walter, F.R.M.S. Derwent, 30 Kelvinside-gardens, Glasgow.
1907. *DIXON, Professor WALTER E., F.R.S. The Museums, Cambridge.
1914. §Dixon, Mrs. W. E. The Grove, Whittlesford, Cambridge.
1902. ‡*Dixon, W. V. Scotch Quarter, Carrickfergus.*
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, Sir James J., D.Sc., LL.D., F.R.S., Principal of the Government Laboratories, 13 Clement's Inn-passage, W.C.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A., J.P., D.L. Castle Dobbs, Carrickfergus, Co. Antrim.
1902. ‡Dobbs, F. W., M.A. Eton College, Windsor.
1914. §Docker, His Honour Judge E. B., M.A. Mostyn, Elizabeth Bay, Sydney, N.S.W.
1908. ‡DODD, Hon. Mr. Justice. 26 Fitzwilliam-square, Dublin.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1912. §Don, A. W. R. The Lodge, Broughty Ferry, Forfarshire.
1912. ‡Don, Alexander, M.A., F.R.C.S. Park House, Nethergate, Dundee.
1912. ‡Don, Robert Bogle, M.A. The Lodge, Broughty Ferry, Forfarshire.
1904. ‡Doncaster, Leonard, M.A. Museum of Zoology, Cambridge.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. ‡Donnan, F. G., M.A., Ph.D., F.R.S., Professor of Chemistry in University College, Gower-street, W.C.
1905. §Dornan, Rev. S. S. P.O. Box 510, Bulawayo, South Rhodesia, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1909. ‡Douglas, A. J., M.D. City Health Department, Winnipeg, Canada.
1909. *Douglas, James. 99 John-street, New York, U.S.A.
1912. ‡Doune, Lord. Kinfauns Castle, Perth.

Year of Election.

1903. ‡*Dow, Miss Agnes R.* 81 *Park-mansions, Knightsbridge, S.W.*
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. Landhurst Wood, Hartfield, Sussex.
1913. ‡Dracopoli, J. N. Pollard's Wood Grange, Chalfont St. Giles, Buckinghamshire.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1912. §Drever, James, M.A., B.Sc. 36 Morningside-grove, Edinburgh.
1905. ‡Drew, H. W., M.B., M.R.C.S. Mocollup Castle, Ballyduff, S.O., Co. Waterford.
1906. *Drew, Joseph Webster, M.A., LL.M. Hatherley Court, Cheltenham.
1906. *Drew, Mrs. Hatherley Court, Cheltenham.
1908. ‡Droop, J. P. 11 Cleveland-gardens, Hyde Park, W.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. (Local Sec. 1894.) Yardley Lodge, 9 Crick-road, Oxford.
1909. *Drugman, Julien, Ph.D., M.Sc. 117 Rue Gachard, Brussels.
1907. ‡Drysdale, Charles V., D.Sc. Queen Anne's-chambers, S.W.
1892. ‡Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1856. *DUCIE, The Right Hon. HENRY JOHN REYNOLDS MORETON, Earl of, G.C.V.O., F.R.S., F.G.S. 16 Portman-square, W.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.D., Sc.D. Jesus College, Cambridge.
1895. *Duddell, William, F.R.S. 47 Hans-place, S.W.
1914. §Duff, Frank Gee. 31 Queen-street, Melbourne.
1914. §Duffield, D. Walter. 13 Cowra-chambers, Grenfell-street, Adelaide, South Australia.
1912. §Duffield, Francis A., M.B. Holmleigh, Manor-road, Sutton Coldfield.
1904. *DUFFIELD, Professor W. GEOFFREY, D.Sc. University College, Reading.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1899. *Dugdale-Bradley, J. W., M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C.
1911. ‡Dummer, John. 85 Cottage-grove, Southsea.
1909. ‡Duncan, D. M., M.A. 83 Spence-street, Winnipeg, Canada.
1913. §Dunlop, Dr. Andrew. Belgrave House, St. Helier, Jersey.
1910. ‡Dunn, Rev. J. Road Hill Vicarage, Bath.
1876. ‡Dunnachie, James. 48 West Regent-street, Glasgow.
1884. §Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1893. *Dunstan, M. J. R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *DUNSTAN, WYNDHAM R., C.M.G., M.A., LL.D., F.R.S., F.C.S. (Pres. B, 1906; Council, 1905–08), Director of the Imperial Institute, S.W.
1911. ‡Dupree, Colonel Sir W. T. Craneswater, Southsea.
1913. §Durie, William. Sunnyside, Beechwood-avenue, Finchley, N.
1914. §DU TOIT, A. L., D.Sc. South African Museum, Cape Town.
1914. §Du Toit, Mrs. South African Museum, Cape Town.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Pretoria.
1910. ‡Dutton, F. V., B.Sc. County Agricultural Laboratories, Richmond-road, Exeter.
1895. *DWERRYHOUSE, ARTHUR R., D.Sc., F.G.S. Deraness, Deramore Park, Belfast.
1911. ‡Dye, Charles. Woodcrofts, London-road, Portsmouth.

Year of Election.

1885. *Dyer, Henry, M.A., D.Sc., LL.D. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. *DYSON, Sir F. W., M.A., F.R.S. (Council, 1905–11, 1914–), Astronomer Royal, Royal Observatory, Greenwich, S.E.
1910. ‡Dyson, W. H. Maltby Colliery, near Rotherham, Yorkshire.

1912. ‡Earland, Arthur, F.R.M.S. 34 Granville-road, Watford.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1909. *Easterbrook, C. C., M.A., M.D. Crichton Royal Institution, Dumfries.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1906. *Ebbs, Mrs. A. B. Tuborg, Plaistow-lane, Bromley, Kent.
1909. ‡Eccles, J. R. Gresham's School, Holt, Norfolk.
1903. *ECCLES, W. H., D.Sc. 26 Ridgmount-gardens, Gower-street, W.C
1908. *Eddington, A. S., M.A., M.Sc., F.R.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Trinity College, Cambridge.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1858. *Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1911. *Edge, S. F. Gallops Homestead, Ditchling, Sussex.
1911. *Edgell, Miss Beatrice. Bedford College, Baker-street, W.
1884. *Edgell, Rev. R. Arnold, M.A. Beckley Rectory, East Sussex.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889 ; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Moulsecombe-place, Brighton.
1901. *EDRIDGE-GREEN, F. W., M.D., F.R.C.S. 99 Walm-lane, Willesden Green, N.W.
1914. §Edwards, A. F. Chemical Department, The University, Manchester.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 13 Acris-street, Wandsworth Common, S.W.
1913. §Edwards, E. J. Royal Technical College, Glasgow.
1903. ‡Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.
1901. ‡Eggar, W. D. Eton College, Windsor.
1909. ‡Eggertson, Arni. 120 Emily-street, Winnipeg, Canada.
1909. §Ehrenborg, G. B. 63 Fairfield-building, Vancouver, B.C., Canada.
1907. *Elderton, W. Palin. 74 Mount Nod-road, Streatham, S.W.
1890. ‡Elford, Percy. 115 Woodstock-road, Oxford.
1913. ‡Elkington, Herbert F. Clunes, Wentworth-road, Sutton Coldfield.
1901. *Elles, Miss Gertrude L., D.Sc. Newnham College, Cambridge.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904 ‡Elliot, R. H. Clifton Park, Kelso, N.B.
1905. ‡Elliott, C. C., M.D. Church-square, Cape Town.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.

Year of Election.

Elliott, John Fogg. Elvet Hill, Durham.
1912. §Elliott, Dr. W. T., F.Z.S. 21 Bennett's-hill, Birmingham.
1906. *Ellis, David, D.Sc., Ph.D. Royal Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §Ellis, Herbert. The Gynsills, Groby-road, Leicester.
1913. ‡Ellis, Herbert Willoughby, A.M.Inst.C.E. Holly Hill, Berkswell, Warwickshire.
1880. **Ellis, John Henry.* (*Local Sec.* 1883.) 10 *The Crescent, Plymouth.*
1891. §Ellis, Miss M. A. Care of Miss Rice, 11 Canterbury-road, Oxford.
1906. ‡Elmhirst, Charles E. (Local Sec. 1906.) 29 Mount-vale, York.
1910. ‡Elmhirst, Richard. Marine Biological Station, Millport.
1911. ‡Elwes, H. J., F.R.S. Colesborne Park, near Cheltenham.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1905. ‡Epps, Mrs. Dunhurst, Petersfield, Hampshire.
1894. ‡Erskine-Murray, J., D.Sc., F.R.S.E. 4 Great Winchester-street, E.C.
1914. §Erson, Dr. E. G. Leger. 123 Collins-street, Melbourne.
1862. *Esson, William, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1911. ‡Etherton, G. Hammond. (Local Sec. 1911.) Town Hall, Portsmouth.
1897. *Evans, Lady. Care of Union of London and Smith's Bank, Berkhamsted, Herts.
1889. *Evans, A. H., M.A. 9 Harvey-road, Cambridge.
1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *Evans, Sir Arthur John, M.A., LL.D., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.
1908. ‡Evans, Rev. Henry, D.D., Commissioner of National Education, Ireland. Blackrock, Co. Dublin.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1913. §Evans, J. Jameson. 41 Newhall-street, Birmingham.
1910. *Evans, John W., D.Sc., LL.B., F.G.S. 75 Craven Park-road, Harlesden, N.W.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.
1905. ‡Evans, T. H. 9 Harvey-road, Cambridge.
1910. ‡Evans, T. J. The University, Sheffield.
1865. *Evans, William. The Spring, Kenilworth.
1909. ‡Evans, W. Sanford, M.A. (Local Sec. 1909.) 43 Edmonton street, Winnipeg.
1903. ‡*Evatt, E. J., M.B.* 8 *Kyveilog-street, Cardiff.*
1902. *Everett. Percy W. Oaklands, Elstree, Hertfordshire.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. (Local Sec. 1874.) Glenmachan, Belfast.
1913. *Ewen, J. T. 104 King's-gate, Aberdeen.
1913. *Ewen, Mrs. J. T. 104 King's-gate, Aberdeen.
1876. *Ewing, Sir James Alfred, K.C.B., M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906), Director of Naval Education, Admiralty, S.W. Froghole, Edenbridge, Kent.

Year of Election.

1914. §Ewing, Mrs. Peter. The Frond, Uddingston, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1912. §Eyre, Dr. J. Vargas. South-Eastern Agricultural College, Wye, Kent.
Eyton, Charles. Hendred House, Abingdon.

1906. *Faber, George D. 14 Grosvenor-square, W.
1901. *Fairgrieve, M. McCallum. 37 Queen's-crescent, Edinburgh.
1865. *Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1910. ‡Falconer, J. D. The Limes, Little Berkhamsted, Hertford.
1908. ‡Falconer, Robert A., M.A. 44 Merrion-square, Dublin.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., B.A. Vinchelez, Chase Court-gardens, Windmill-hill, Enfield.
1907. *Fantham, H. B., D.Sc., B.A. 100 Mawson-road, Cambridge.
1902. ‡Faren, William. 11 Mount Charles, Belfast.
1892. *Farmer, J. Bretland, M.A., F.R.S., F.L.S. (Pres. K, 1907; Council, 1912–14.) South Park, Gerrard's Cross.
1897. *Farnworth, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1904. ‡Farnworth, Miss Olive. Broadlands, Goldthorn Hill, Wolverhampton.
1885. **Farquharson, Mrs. R. F. O. Tillydrine, Kincardine O'Neil, N.B.*
1905. ‡Farrar, Edward. P.O. Box 1242, Johannesburg.
1913. ‡Farrow, F. D. Rhodes University College. Grahamstown, South Africa.
1903. §Faulkner, Joseph M. 17 Great Ducie-street, Strangeways, Manchester.
1913. §Fawcett, C. B. University College, Southampton.
1890. *Fawcett, F. B. 1 Rockleaze-avenue, Sneyd Park, Bristol.
1906. §Fawcett, Henry Hargreave. Thorncombe, near Chard, Somerset.
1900. ‡Fawcett, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D., Professor of Chemistry in the University of Sydney, New South Wales.
1911. *Fay, Mrs. A. Q. Chedworth, Rustat-road, Cambridge.
1909. *Fay, Charles Ryle, M.A. Christ's College, Cambridge.
1906. *Fearnsides, Edwin G., M.A., M.B., B.Sc. London Hospital, E.
1901. *Fearnsides, W. G., M.A., F.G.S. Sorby Professor of Geology in the University of Sheffield. 10 Silver Birch-avenue, Fulwood, Sheffield.
1910. *Fearnsides, Mrs. 10 Silver Birch-avenue, Fulwood, Sheffield.
1905. ‡Feilden, Colonel H. W., C.B., F.R.G.S., F.G.S. Burwash, Sussex.
1900. *Fennell, William John. Deramore Drive, Belfast.
1904. ‡Fenton, H. J. H., M.A., F.R.S. 19 Brookside, Cambridge.
1914. §Ferguson, E. R. Gordon-street, Footscray, Victoria.
1871. *Ferguson, John, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1901. ‡Ferguson, R. W. 16 Linden-road, Bournville, near Birmingham.
1863. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1910. *Ferranti, S. Z. de, M.Inst.C.E. Grindleford, near Sheffield.
1905. *Ferrar, H. T., M.A., F.G.S. Geological Survey of Egypt, Giza, Egypt.
1914. §Ferrar, Mrs. Geological Survey of Egypt, Giza, Egypt.
1873. ‡Ferrier, Sir David, M.A., M.D., LL.D., F.R.S. 34 Cavendish-square, W.

Year of Election.

1909. ‡Fetherstonhaugh, Professor Edward P., B.Sc. 119 Betourney-street, Winnipeg, Canada.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1913. §Field, Miss E. E. Hollywood, Egham Hill, Surrey.
1897. ‡Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1907. *Fields, Professor J. C., F.R.S. The University, Toronto, Canada.
1906. §FILON, L. N. G., D.Sc., F.R.S., Professor of Applied Mathematics in the University of London. Lynton, Haling Park-road, Croydon.
1905. ‡Fincham, G. H. Hopewell, Invami, Cape Colony.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Professor of Chemistry in University College, Aberystwyth.
1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Ruperra, Victoria Park, Manchester.
1912. §Finlayson, Daniel, F.L.S. Seed Testing Laboratory, Wood Green, N.
1902. ‡Finnegan, J., M.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1902. ‡Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
1909. ‡Fisher, James, K.C. 216 Portage-avenue, Winnipeg, Canada.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1871. *FISON, Sir FREDERICK W., Bart., M.A., F.C.S. Boarzell, Hurst Green, Sussex.
1885. *FITZGERALD, Professor MAURICE, B.A. (Local Sec. 1902.) Fairholme, Monkstown, Co. Dublin.
1894. ‡FITZMAURICE, Sir MAURICE, C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *FITZPATRICK, Rev. THOMAS C., President of Queens' College, Cambridge.
1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1904. ‡Fleming, James. 25 Kelvinside-terrace South, Glasgow.
1913. §Fleming, Professor J. A., D.Sc., F.R.S. University College, Gower-street, W.C.
1892. ‡Fletcher, George, F.G.S. Mona, Shankhill, Co. Dublin.
1888. *FLETCHER, LAZARUS, M.A., Ph.D., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Director of the Natural History Museum, Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S., F.R.S.E. Geological Survey Office, 33 George-square, Edinburgh.
1906. *FLEURE, H. J., D.Sc., Professor of Zoology and Geology in University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1913. *Florence, P. Sargant, B.A. Caius College, Cambridge.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1890. *FLUX, A. W., M.A. Board of Trade, Gwydyr House, Whitehall, S.W.
1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1903. ‡Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.
1911. ‡Foran, Charles. 72 Elm-grove, Southsea.
1906. §Forbes, Charles Mansfeldt. 14 New-street, York.
1914. §Forbes, E. J. P.O. Box 1604, Sydney, N.S.W.
1914. §Forbes, Mrs. E. J. P.O. Box 1604, Sydney, N.S.W.

Year of Election.

1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 11 Little College-street, Westminster, S.W.

1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Redcliffe, Beaconsfield, Bucks.

1905. ‡FORBES, Major W. LACHLAN. Army and Navy Club, Pall Mall, S.W.

1875. *FORDHAM, Sir GEORGE. Odsey, Ashwell, Baldock, Herts.

1909. ‡FORGET, The Hon. A. E. Regina, Saskatchewan, Canada.

1887. ‡FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.

1902. *Forster, M. O., Ph.D., D.Sc., F.R.S. 84 Cornwall-gardens, S.W.

1883. ‡FORSYTH, Professor A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905; Council, 1907–09.) The Manor House, Marylebone, N.W.

1911. ‡Foster, F. G. Ivydale, London-road, Portsmouth.

1857. *FOSTER, GEORGE CAREY, B.A., LL.D., D.Sc., F.R.S. (GENERAL TREASURER, 1898–1904; Pres. A, 1877; Council, 1871–76, 1877–82.) Ladywalk, Rickmansworth.

1914. §Foster, Colonel H. J., R.E. The University, Sydney, N.S.W.

1908. ***Foster, John Arnold.* 11 *Hills-place, Oxford Circus, W.*

1901. ‡Foster, T. Gregory, Ph.D., Provost of University College, London. University College, Gower-street, W.C.

1911. ‡FOSTER, Sir T. SCOTT, J.P. Town Hall, Portsmouth.

1911. ‡Foster, Lady Scott. Braemar, St. Helen's-parade, Southsea.

1903. ‡Fourcade, H. G. P.O., Storms River, Humansdorp, Cape Colony.

1905. §Fowlds, Hiram. 65 Devonshire-street, Keighley, Yorkshire.

1909. §Fowlds, Mrs. 65 Devonshire-street, Keighley, Yorkshire.

1912. ‡Fowler, A., F.R.S., Assistant Professor of Physics in the Imperial College of Science and Technology, S.W. 19 Rusthall-avenue, Bedford Park, W.

1883. *Fox, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.

1883. ‡Fox, Sir CHARLES DOUGLAS, M.Inst.C.E. (Pres. G, 1896.) Cross Keys House, 56 Moorgate-street, E.C.

1904. *Fox, Charles J. J., B.Sc., Ph.D., Professor of Chemistry in the Presidency College of Science, Poona, India.

1904. §Fox, F. Douglas, M.A., M.Inst.C.E. 19 The Square, Kensington, W.

1905. ‡Fox, Mrs. F. Douglas. 19 The Square, Kensington, W.

1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.

1900. *Fox, Thomas. Old Way House, Wellington, Somerset.

1909. *Fox, Wilson Lloyd. Carmino, Falmouth.

1908. §Foxley, Miss Barbara, M.A. 5 Norton Way North, Letchworth.

1881. *FOXWELL, HERBERT S., M.A., F.S.S. (Council, 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.

1907. ‡Fraine, Miss Ethel de, D.Sc., F.L.S. Westfield College, Hampstead, N.W.

1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.

1913. §Franklin, Cyril H. H. 38 Croydon-road, Croydon, Sydney, N.S.W.

1910. *FRANKLIN, GEORGE, Litt.D. Tapton Hall, Sheffield.

1911. ‡FRASER, Dr. A. MEARNS. (Local Sec. 1911.) Town Hall, Portsmouth.

1911. ‡Fraser, Mrs. A. Mearns. Cheyne Lodge, St. Ronan's-road, Portsmouth.

1895. ‡Fraser, Alexander. 63 Church-street, Inverness.

Year of Election.

1871. ‡FRASER, Sir THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1911. §Freeman, Oliver, B.Sc. The Municipal College, Portsmouth.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.
1909. ‡French, Mrs. Harriet A. Suite E, Gline's-block, Portage-avenue, Winnipeg, Canada.
1912. §French, Mrs. Harvey. Hambledon Lodge, Childe Okeford, Blandford.
1905. ‡French, Sir Somerset R., K.C.M.G. 100 Victoria-street, S.W.
1886. ‡FRESHFIELD, DOUGLAS W., F.R.G.S. (Pres. E, 1904.) 1 Airlie-gardens, Campden Hill, W.
1887. *Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1906. ‡FRITSCH, Dr. F. E. 77 Chatsworth-road, Brondesbury, N.W.
1912. §Frodsham, Miss Margaret, B.Sc. The College School, 34 Cathedral-road, Cardiff.
1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1911. ‡Frost, M. E. P. H.M. Dockyard, Portsmouth.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W.
1898. ‡FRY, The Right Hon. Sir EDWARD, G.C.B., D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1908. ‡Fry, M. W. J., M.A. 39 Trinity College, Dublin.
1905. *Fry, William, J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1912. §Fulton, Angus R., B.Sc. University College, Dundee.
1913. *Fyson, Philip Furley, B.A., F.L.S. Elmley Lovett, Droitwich.

1910. ‡GADOW, H. F., Ph.D., F.R.S. (Pres. D., 1913). Zoological Laboratory, Cambridge.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1906. ‡Gajjar, Professor T. K., M.A., B.Sc. Techno-Chemical Laboratory, near Girgaum Tram Terminus, Bombay.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J. The Cottage, Seymour-grove, Old Trafford, Manchester.
1905. ‡Galpin, Ernest E. Bank of Africa, Queenstown, Cape of Good Hope.
1913. §GAMBLE, F. W., D.Sc., F.R.S. (Local Sec., 1913), Professor of Zoology and Comparative Anatomy in the University of Birmingham. 38 Frederick-road, Edgbaston, Birmingham.
1888. *GAMBLE, J. SYKES, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.
1911. ‡Garbett, Rev. C. F., M.A. The Vicarage, Fratton-road, Portsmouth.
1899. *Garcke, E. Ditton House, near Maidenhead.
1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1911. ‡Gardiner, C. I., M.A., F.G.S. 6 Paragon-parade, Cheltenham.
1912. §Gardiner, F. A., F.L.S. Inversnaid, West Heath-avenue, N.W.
1905. ‡Gardiner, J. H. 59 Wroughton-road, Balham, S.W.
1900. ‡GARDINER, J. STANLEY, M.A., F.R.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Zoological Laboratory, Cambridge.
1887. ‡GARDINER, WALTER, M.A., D.Sc., F.R.S. St. Awdreys, Hills-road, Cambridge.

Year of Election.

1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1912. *Gardner, Willoughby, F.L.S. Y Berlfa, Deganwy, North Wales.
1912. §Garfitt, G. A. Cartledge Hall, Holmesfield, near Sheffield.
1913. *Garnett, Principal J. C. Maxwell, M.A. (Local Secretary, 1915.) Westfield, Victoria Park, Manchester.
1905. ‡Garnett, Mrs. Maxwell, F.Z.S. Westfield, Victoria Park, Manchester.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Victoria Embankment, W.C.
1883. ‡Garson, J. G., M.D. (Assist. Gen. Sec. 1902–04.) Moorcote, Eversley, Winchfield.
1903. ‡Garstang, A. H. 82 Forest-road, Southport.
1903. *Garstang, T. James, M.A. Bedales School, Petersfield, Hampshire.
1894. *Garstang, Walter, M.A., D.Sc., F.Z.S., Professor of Zoology in the University of Leeds.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1889. ‡Garwood, E. J., M.A., F.R.S., F.G.S. (Pres. C, 1913), Professor of Geology in the University of London. University College, Gower-street, W.C.
1905. ‡Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.
1905. ‡Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.
1906. ‡Gaster, Leon. 32 Victoria-street, S.W.
1913. §Gates, R. R., Ph.D., F.L.S. 14 Well-walk, Hampstead, N.W.
1911. ‡Gates, W. 'Evening News' Office, Portsmouth.
1912. §Gavin, W., M.A. The Farms Offices, Blenheim Park, Woodstock.
1905 *Gearon, Miss Susan. 55 Buckleigh-road, Streatham Common, S.W.
1885. ‡Geddes, Professor Patrick. 14 Ramsay-gardens, Edinburgh.
1867. ‡Geikie, Sir Archibald, O.M., K.C.B., LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S. (President, 1892; Pres. C, 1867, 1871, 1899; Council, 1888–1891.) Shepherd's Down, Haslemere, Surrey.
1913. §Geldart, Miss Alice M. 2 Cotman-road, Norwich.
1898. *Gemmill, James F., M.A., M.D. 12 Anne-street, Hillhead, Glasgow.
1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1905. ‡Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
1912. *George, H. Trevelyan, M.A., M.R.C.S., L.R.C.P. 33 Ampthill-square, N.W.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
1899. *Gepp, Mrs. A. British Museum (Natural History), Cromwell-road, S.W.
1913. §Gerich, Miss Emma A. P. Care of The Manager, Bank of Australasia, Sydney, Australia.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1909. ‡Gibbons, W. M., M.A. (Local Sec. 1910.) The University, Sheffield.
1905. ‡Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W.

Year of Election.

1912. ‡Gibson, A. H., D.Sc., Professor of Engineering in University College, Dundee.
1914. §Gibson, A. J., Ph.D. Central Sugar Mills, Brisbane, Australia.
1912. ‡Gibson, G. E., Ph.D., B.Sc. 16 Woodhall-terrace, Juniper Green.
1901. ‡Gibson, Professor George A., M.A. 10 The University, Glasgow.
1904. *Gibson, Mrs. Margaret D., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1912. *Gibson, Miss Mary H., M.A., Ph.D. 75 Colum-road, Cardiff.
1896. ‡GIBSON, R. J. HARVEY, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893 ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1898. *Gifford, J. William. Oaklands, Chard.
1883. ‡Gilbert, Lady. Park View, Englefield Green, Surrey.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡GILCHRIST, J. D. F., M.A., Ph.D., B.Sc., F.L.S. Marine Biologist's Office, Department of Agriculture, Cape Town.
1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Reform Club, Pall Mall, S.W.
1911. ‡Gill, Rev. H. V., S.J. Milltown Park, Clonskea, Co. Dublin.
1902. ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1908. ‡Gill, T. P. Department of Agriculture and Technical Instruction for Ireland, Dublin.
1913. *Gillett, Joseph A., B.A. Woodgreen, Banbury.
1913. ‡Gillmor, R. E. 57 Victoria-street, S.W.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. ‡Gilmour, S. C. 25 Cumberland-road, Acton, W.
1908. ‡*Gilmour, T. L. 1 St. John's Wood Park, N.W.*
1913. §Gilson, R. Cary, M.A. King Edward's School, Birmingham.
1913. §Gimingham, C. T., F.I.C. Research Station, Long Ashton, Bristol.
1893. *Gimingham, Edward. Croyland, Clapton Common, N.E.
1904. ‡GINN, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1884. ‡Girdwood, G. P., M.D. 615 University-street, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Yoxall, Rural Route No. 1—Ladysmith, British Columbia, Canada.
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890; Council, 1878–86.) Trinity College, Cambridge.
1880. *GLANTAWE, Right Hon. Lord. The Grange, Swansea.
1881. *GLAZEBROOK, R. T., C.B., M.A., D.Sc., F.R.S. (Pres. A, 1893; Council 1890–94, 1905–11), Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
Glover, Thomas. 124 Manchester-road, Southport.
1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
1880. ‡GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 45 Pont-street, S.W.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883.) Nore, Godalming.
1878. ‡GOFF, JAMES. (Local Sec. 1878.) 29 Lower Leeson-street, Dublin.
1908. *GOLD, ERNEST, M.A. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W.

Year of
Election.

1914. §Gold, Mrs. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W.

1906. ‡GOLDIE, Right Hon. Sir GEORGE D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906-07.) Naval and Military Club, 94 Piccadilly, W.

1910. §Golding, John, F.I.C. University College, Reading.

1913. §Golding, Mrs. University College, Reading.

1899. ‡GOMME, *Sir G. L., F.S.A.*

1890. *GONNER, E. C. K., M.A. (Pres. F, 1897, 1914), Professor of Economic Science in the University of Liverpool. Undercliff, West Kirby, Cheshire.

1909. ‡Goodair, Thomas. 303 Kennedy-street, Winnipeg, Canada.

1912. §Goodman, Sydney, C. N., B.A. 1 Brick-court, Temple, E.C.

1907. §GOODRICH, E. S., M.A., F.R.S., F.L.S. Merton College, Oxford.

1908. ‡Goodrich, Mrs. Merton College, Oxford.

1884. *Goodridge, Richard E. W. P.O. Box 36, Coleraine, Minnesota, U.S.A.

1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.

1909. §Gordon, Rev. Charles W. 567 Broadway, Winnipeg, Canada.

1909. ‡Gordon, J. T. 147 Hargrave-street, Winnipeg, Canada.

1909. ‡Gordon, Mrs. J. T. 147 Hargrave-street, Winnipeg, Canada.

1911. *Gordon, J. W. 113 Broadhurst-gardens, Hampstead, N.W.

1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.

1893. ‡Gordon, Mrs. M. M. Ogilvie, D.Sc. 1 Rubislaw-terrace, Aberdeen.

1910. *Gordon, Vivian. Avonside Engine Works, Fishponds, Bristol.

1912. §Gordon, W. T. Geological Department, King's College, Strand, W.C.

1901. ‡GORST, Right Hon. Sir JOHN E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901.) 84 Campden Hill Court, W.

1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.

1901. ‡GOURLAY, ROBERT. Glasgow.

1876. ‡Gow, Robert. Cairndowan, Dowanhill-gardens, Glasgow.

1883. ‡Gow, Mrs. Cairndowan, Dowanhill-gardens, Glasgow.

1873. ‡Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.

1908. *GRABHAM, G. W., M.A., F.G.S. P.O. Box 178, Khartoum, Sudan.

1886. ‡Grabham, Michael C., M.D. Madeira.

1909. ‡GRACE, J. H., M.A., F.R.S. Peterhouse, Cambridge.

1909. ‡Graham, Herbert W. 329 Kennedy-street, Winnipeg, Canada.

1902. *Graham, William, M.D. Purdysburn House, Belfast.

1914. §Graham, Mrs. Purdysburn House, Belfast.

1875. ‡GRAHAME, JAMES. (Local Sec. 1876.) Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.

1904. §Gramont, Comte Arnaud de, D.Sc. 179 rue de l'Université, Paris.

1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.

1914. §GRANT, KERR, M.Sc., Professor of Physics in the University of Adelaide, South Australia.

1908. *Grant, Professor W. L. Queen's University, Kingston, Ontario.

1914. §Grasby, W. C. Care of G. J. W. Grasby, Esq., Grenfell-street, Adelaide, South Australia.

1890. ‡GRAY, ANDREW, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.

1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.

1881. ‡Gray, Edwin, LL.B. Minster-yard, York.

1903. §Gray, Ernest, M.A. 104 Tulse-hill, S.W.

Year of Election.

1904. ‡GRAY, Rev. H. B., D.D. (Pres. L, 1909). Pinecroyd, Lower Bourne, Farnham.
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
1887. ‡Gray, Joseph W., F.G.S. 6 Richmond Park-crescent, Bournemouth.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1901. ‡Gray, R. Whytlaw. University College, W.C.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1910. ‡Greaves, R. H., B.Sc. 12 St. John's-crescent, Cardiff.
1904. *Green, Professor A. G., M.Sc. The Old Gardens, Cardigan-road, Headingley, Leeds.
1904. §Green, F. W. 5 Wordsworth-grove, Cambridge.
1906. §Green, J. A., M.A., Professor of Education in the University of Sheffield.
1908. ‡Green, Rev. William Spotswood, C.B., F.R.G.S. 5 Cowper-villas, Cowper-road, Dublin.
1909. ‡Greenfield, Joseph. P.O. Box 2935, Winnipeg, Canada.
1882. ‡GREENHILL, Sir A. G., M.A., F.R.S. 1 Staple Inn, W.C.
1905. ‡Greenhill, William. 6A George-street, Edinburgh.
1913. *Greenland, Miss Lucy Maud. St. Hilda's, Hornsea, East Yorkshire.
1898. *GREENLY, EDWARD, F.G.S. Achnashean, near Bangor, North Wales.
1875. ‡Greenwood, Dr. Frederick. Brampton, Chesterfield.
1906. ‡Greenwood, Sir Hamar, Bart., M.P. National Liberal Club, Whitehall-place, S.W.
1894. *GREGORY, J. WALTER, D.Sc., F.R.S., F.G.S. (Pres. C, 1907), Professor of Geology in the University of Glasgow.
1896. *GREGORY, Professor R. A., F.R.A.S. Walcot, Blyth-road, Bromley, Kent.
1904. *GREGORY, R. P., M.A. St. John's College, Cambridge.
1914. §Gregory, Miss V. J. The University, Glasgow.
1914. §Grew, Mrs. 30 Cheyne-row, S.W.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E., Professor of Civil Engineering in the College of Engineering, Madras.
1908. §Griffith, Sir John P., M.Inst.C.E. Rathmines Castle, Rathmines, Dublin.
1884. ‡GRIFFITHS, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906; Pres. L, 1913; Council, 1911-), Principal of University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1903. ‡Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St. Stephen's Club, Westminster, S.W.
1914. §Grinley, Frank. Wandella, Gale-street, Woolwich, N.S.W.
1911. ‡Grogan, Ewart S. Camp Hill, near Newcastle, Staffs.
1894. ‡GROOM, Professor P., M.A., F.L.S. North Park, Gerrard's Cross, Bucks.
1894. ‡Groom, T. T., M.A., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1909. *Grossman, Edward L., M.D. Steilacoom, Washington, U.S.A.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1913. ‡Grove, W. B., M.A. 45 Duchess-road, Edgbaston, Birmingham.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Aberfoyle, Rathgar, Dublin.

Year of
Election.

1913. §Gruchy, G. F. B. de. Bulwark House, St Aubin, Jersey.
1897. ‡Grünbaum, A. S., M.A., M.D. School of Medicine, Leeds.
1910. §Grundy, James. Ruislip, Teignmouth-road, Cricklewood, N.W.
1913. ‡Guest, James J. 11 St. Mark's-road, Leamington.
1887. ‡GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W.
1909. ‡Gunne, J. R., M.D. Kenora, Ontario, Canada.
1909. ‡Gunne, W. J., M.D. Kenora, Ontario, Canada.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. §Gurney, Sir Eustace. Sprowston Hall, Norwich.
1902. *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
1911. §Guthrie, Mrs. Blanche. 72 Ladbroke-grove, W.
1904. ‡Guttmann, Professor Leo F., Ph.D. Queen's University, Kingston, Canada.
1895. *GWYNNE-VAUGHAN, D. T., F.L.S., Professor of Botany in University College, Reading.
1906. *GWYNNE-VAUGHAN, Mrs. HELEN C. I., D.Sc., F.L.S. Department of Botany, Birkbeck College; and 27 Lincoln's Inn-fields, W.C.

1905. ‡Hacker, Rev. W. J. Idutywa, Transkei, South Africa.
1908. *Hackett, Felix E. Royal College of Science, Dublin.
1881. *HADDON, ALFRED CORT, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902, 1905; Council, 1902–08, 1910– .) 3 Cranmer-road, Cambridge.
1914. §Haddon, Mrs. 3 Cranmer-road, Cambridge.
1911. *Haddon, Miss Kathleen. 3 Cranmer-road, Cambridge.
1888. *Hadfield, Sir Robert, D.Met., D.Sc., F.R.S., M.Inst.C.E. 22 Carlton House-terrace, S.W.
1913. ‡Hadley, H. E., B.Sc. School of Science, Kidderminster.
1905. ‡Hahn, Professor P. H., M.A., Ph.D. York House, Gardens, Cape Town.
1911. ‡Haigh, B. P., B.Sc. James Watt Engineering Laboratory, The University, Glasgow.
1906. ‡Hake, George W. Oxford, Ohio, U.S.A.
1894. ‡HALDANE, JOHN SCOTT, M.A., M.D., F.R.S. (Pres. I, 1908), Reader in Physiology in the University of Oxford. Cherwell, Oxford.
1909. §Hale, W. H., Ph.D. 40 First-place, Brooklyn, New York, U.S.A.
1911. §Halket, Miss A. C. Waverley House, 135 East India-road, E.
1899. ‡HALL, A. D., M.A., F.R.S. (Pres. M, 1914; Council, 1908– .) Development Commission, 6A Dean's-yard, S.W.
1914. §Hall, Mrs. A. D. Ewhurst, Mostyn-road, Merton.
1909. §Hall, Archibald A., M.Sc., Ph.D. Armstrong College, Newcastle-on-Tyne.
1903. ‡HALL, E. MARSHALL, K.C. 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. 63 Belmont-street, Southport.
1854. *HALL, HUGH FERGIE, F.G.S. Cissbury Court, West Worthing, Sussex.
1899. ‡Hall, John, M.D. National Bank of Scotland, Nicholas-lane, E.C.
1884. §Hall, Thomas Proctor, M.D. 1301 Davie-street, Vancouver, B.C., Canada.
1908. *Hall, Wilfred, Assoc.M.Inst.C.E. 9 Prior's-terrace, Tynemouth, Northumberland.
1913. ‡Hall-Edwards, J. The Elms, 112 Gough-road, Edgbaston, Birmingham.

Year of Election.

1891. *Hallett, George. Oak Cottage, West Malvern.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., LL.D., F.R.S. (Pres. I, 1902 ; Council, 1897–1903, 1911–), Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, N.W.
1905. ‡Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W.
1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
1908. *Hamel, Egbert Alexander de. Middleton Hall, Tamworth.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
1906. ‡Hamilton, Charles I. 88 Twyford-avenue, Acton.
1909. ‡Hamilton, F. C. Bank of Hamilton-chambers, Winnipeg, Canada.
1902. ‡HAMILTON, Rev. T., D.D. Queen's College, Belfast.
1909. ‡Hamilton, T. Glen, M.D. 264 Renton-avenue, Winnipeg, Canada.
1881. *HAMMOND, ROBERT, M.Inst.C.E. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
1878. ‡Hance, E. M. Care of J. Hope Smith, Esq., 3 Leman-street, E.C.
1909. ‡Hancock, C. B. Manitoba Government Telephones, Winnipeg, Canada.
1905. *Hancock, Strangman. Kennel Holt, Cranbrook, Kent.
1912. ‡Hankin, G. T. 150 Whitehall-court, S.W.
1911. ‡Hann, H. F. 139 Victoria-road North, Southsea.
1906. § Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. Woodthorpe, Royston Park-road, Hatch End. Middlesex.
1914. §Happell, Mrs. Care of Miss E. M. Bundey, Molesworth Street, North Adelaide, South Australia.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.C.S. (GEN. SEC. 1883–97 ; Pres. B, 1875 ; Council, 1881–83.) St. Clare, Ryde, Isle of Wight.
1909. §Harcourt, George. Department of Agriculture, Edmonton, Alberta, Canada.
1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1902. *HARDCASTLE, Miss FRANCES. 3 Osborne-terrace, Newcastle-on-Tyne.
1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
1892. *HARDEN, ARTHUR, Ph.D., D.Sc., F.R.S. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
1905. ‡*Hardie, Miss Mabel, M.B. High-lane,* via *Stockport.*
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1913. ‡Hardy, George Francis. 30 Edwardes-square, Kensington, W.
1909. ‡HARDY, W. B., M.A., F.R.S. Gonville and Caius College, Cambridge.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. *HARKER, ALFRED, M.A., F.R.S., F.G.S. (Pres. C, 1911.) St. John's College, Cambridge.
1914. §Harker, Dr. George. The University, Sydney, N.S.W.
1896. ‡Harker, John Allen, D.Sc., F.R.S. National Physical Laboratory, Bushy House, Teddington.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rastrick, Cricketfield-road, Torquay.

Year of Election.

1899. ‡Harman, Dr. N. Bishop, F.R.C.S. 108 Harley street, W.
1913. ‡Harmar, Mrs. 102 Hagley-road, Birmingham.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., Sc.D., F.R.S. (Pres. D, 1908). Keeper of the Department of Zoology, British Museum (Natural History), Cromwell-road, S.W.
1912. *Harper, Alan G., B.A. Magdalen College, Oxford.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1913. ‡Harris, F. W. 132 and 134 Hurst-street, Birmingham.
1842. *Harris, G. W. Millicent, South Australia.
1909. ‡Harris, J. W. Civic Offices, Winnipeg.
1903. ‡Harris, Robert, M.B. Queen's-road, Southport.
1904. *Harrison, Frank L., B.A., B.Sc. Brook-street, Soham, Cambridgeshire.
1904. ‡HARRISON, H. SPENCER. The Horniman Museum, Forest Hill, S.E.
1892. ‡HARRISON, JOHN. (Local Sec. 1892.) Rockville, Napier-road, Edinburgh.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1901. *Harrison, W. E. 17 Soho-road, Handsworth, Staffordshire.
1911. ‡Harrison-Smith, F., C.B. H.M. Dockyard, Portsmouth.
1885. ‡HART, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
1909. ‡Hart, John A. 120 Emily-street, Winnipeg, Canada.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. §Hart, W. E. Kilderry, near Londonderry.
1911. ‡Hart-Synnot, Ronald V.O. University College, Reading.
1893. *HARTLAND, E. SIDNEY, F.S.A. (Pres. H, 1906 ; Council, 1906-13.) Highgarth, Gloucester.
1905. ‡Hartland, Miss. Highgarth, Gloucester.
1886. *HARTOG, Professor M. M., D.Sc. University College, Cork.
1887. ‡HARTOG, P. J., B.Sc. University of London, South Kensington, S.W.
1885. §Harvie-Brown, J. A., LL.D. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1893. §Haslam, Lewis. 8 Wilton-crescent, S.W.
1911. *Hassé, H. R. The University, Manchester.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
1904. ‡HASTINGS, G. 23 Oak-lane, Bradford, Yorkshire.
1875. *HASTINGS, G. W. (Pres. F, 1880.) Chapel House, Chipping Norton.
1903. ‡Hastings, W. G. W. 2 Halsey-street, Cadogan-gardens, S.W.
1889. ‡HATCH, F. H., Ph.D., F.G.S. 15 Copse-hill, Wimbledon, S.W.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1908. §Havelock, T. H., M.A., D.Sc., F.R.S. Rockliffe, Gosforth, Newcastle-on-Tyne.
1904. ‡Havilland, Hugh de. Eton College, Windsor.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. (Council, 1881–87.) 22 Down-street, W.
1897. §HAWKSLEY, CHARLES, M.Inst.C.E., F.G.S. (Pres. G, 1903 ; Council, 1902–09.) Caxton House (West Block), Westminster, S.W.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1913. ‡Haworth, John F. Withens, Barker-road, Sutton Coldfield.
1913. ‡Haworth, Mrs. Withens, Barker-road, Sutton Coldfield.

Year of Election.

1885. *HAYCRAFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
1900. §Hayden, H. H., B.A., F.G.S. Geological Survey, Calcutta, India.
1903. *Haydock, Arthur. 114 Revidge-road, Blackburn.
1913. §Hayward, Miss. 7 Abbotsford-road, Galashiels, N.B.
1903. ‡Hayward, Joseph William, M.Sc. Keldon, St. Marychurch, Torquay.
1896. *Haywood, Colonel A. G. Rearsby, Merrilocks-road, Blundellsands.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. 10 King's Bench-walk, Temple, E.C.
1909. ‡Heard, Mrs. Sophie, M.B., Ch.B. Carisbrooke, Fareham, Hants.
1908. §Heath, J. St. George, B.A. The Warden's Lodge, Toynbee Hall, Commercial-street, E.
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W.
1898. ‡HEATH, R. S., M.A., D.Sc., Vice-Principal and Professor of Mathematics in the University of Birmingham.
1909. ‡Heathcote, F. C. C. Broadway, Winnipeg, Canada.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1913. §HEATON, HOWARD. (Local Sec., 1913.) Wayside, Lode-lane, Solihull, Birmingham.
1892. *HEATON, WILLIAM H., M.A. (Local Sec., 1893), Principal of and Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West, I.S.O. 12 Tring-avenue, Ealing, W.
1888. *HEAWOOD, EDWARD, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J., Professor of Mathematics in Durham University. High Close, Hollinside-lane, Durham.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W.
1912. §HEDLEY, CHARLES. Australian Museum, Sydney.
1881. *HELE-SHAW, H. S., D.Sc., LL.D., F.R.S., M.Inst.C.E. 64 Victoria-street, S.W.
1901. *HELLER, W. M., B.Sc. Education Office, Marlborough-street, Dublin.
1911. ‡Hellyer, Francis E. Farlington House, Havant, Hants.
1911. ‡Hellyer, George E. Farlington House, Havant, Hants.
1887. ‡Hembry, Frederick William, F.R.M.S. City-chambers, 2 St. Nicholas-street, Bristol.
1908. ‡Hemmy, Professor A. S. Government College, Lahore.
1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1905. *Henderson, Andrew. 17 Belhaven-terrace, Glasgow.
1905. *Henderson, Miss Catharine. 17 Belhaven-terrace, Glasgow.
1891. *HENDERSON, G. G., D.Sc., M.A., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College, Glasgow.
1905. §Henderson, Mrs. 7 Marlborough-drive, Kelvinside, Glasgow.
1907. ‡Henderson, H. F. Felday, Morland-avenue, Leicester.
1906. ‡Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1909. ‡Henderson, Veylien E. Medical Building, The University, Toronto, Canada.
1880. *Henderson, Admiral W. H., R.N. 3 Onslow Houses, S.W.
1911. ‡Henderson, William Dawson. The University, Bristol.
1904. *Hendrick, James. Marischal College, Aberdeen.
1910. ‡Heney, T. W. Sydney, New South Wales.
1910. *HENRICI, Captain E. O., R.E., A.Inst.C.E. Ordnance Survey Office, Southampton.

Year of Election.

1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883–89.) Hiltingbury Lodge, Chandler's Ford, Hants.
1910. ‡Henry, Hubert, M.D. 304 Glossop-road, Sheffield.
1906. ‡Henry, Dr. T. A. Imperial Institute, S.W.
1909. *Henshall, Robert. Sunnyside, Latchford, Warrington.
1892. ‡HEPBURN, DAVID, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. ‡Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, South Kensington, S.W.
1892. *HERBERTSON, A. J., M.A., Ph.D. (Pres. E, 1910), Professor of Geography in the University of Oxford. 9 Fyfield-road, Oxford.
1909. ‡Herbinson, William. 376 Ellice-avenue, Winnipeg, Canada.
1914. *Herdman, Miss C. Croxteth Lodge, Sefton Park, Liverpool.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1912. *Herdman, George Andrew. Croxteth Lodge, Sefton Park, Liverpool.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S. (GENERAL SECRETARY, 1903– ; Pres. D, 1895; Council, 1894–1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1909. ‡Herdt, Professor L. A. McGill University, Montreal, Canada.
1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
1912. ‡Heron, David, D.Sc. Galton Eugenics Laboratory, University College, W.C.
1912. ‡Heron-Allen, Edward, F.L.S., F.G.S. 33 Hamilton-terrace, N.W.
1908. *Herring, Percy T., M.D., Professor of Physiology in the University, St. Andrews, N.B.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, Rev. J. C. W. Fircroft, Wellington College Station, Berkshire.
1913. ‡Hersey, Mayo Dyer, A.M. Bureau of Standards, Washington, U.S.A.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *HESKETH, CHARLES H. FLEETWOOD, M.A. Stocken Hall, Stretton, Oakham.
1895. §Hesketh, James. 5 Scarisbrick Avenue, Southport.
1913. §Hett, Miss Mary L. 53 Fordwych-road, West Hampstead, N.W.
1894. ‡HEWETSON, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. ‡*Hewins, W. A. S., M.A., F.S.S.* 15 *Chartfield-avenue, Putney Hill, S.W.*
1908. ‡Hewitt, Dr. C. Gordon. Central Experimental Farm, Ottawa.
1896. §Hewitt, David Basil, M.D. Oakleigh, Northwich, Cheshire.
1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1909. ‡Hewitt, Sir Frederic, M.V.O., M.D. 14 Queen Anne-street, W.
1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D., F.R.S. Clifford House, Staines-road, Bedfont, Middlesex.
1909. ‡Hewitt, W., B.Sc. 16 Clarence-road, Birkenhead.
1882. *HEYCOCK, CHARLES T., M.A., F.R.S. 3 St. Peter's-terrace, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. St. Barnabas Vicarage, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.

Year of Election.

1912. §Heywood, H. B., D.Sc. 40 Manor-way, Ruislip.
1912. ‡Hickling, George. The University, Manchester.
1877. §Hicks, W. M., M.A., D.Sc., F.R.S. (Pres. A, 1895), Professor of Physics in the University of Sheffield. Leamhurst, Ivy Park-road, Sheffield.
1886. ‡Hicks, Mrs. W. M. Leamhurst, Ivy Park-road, Sheffield.
1887. *Hickson, Sydney J., M.A., D.Sc., F.R.S. (Pres. D, 1903; Local Secretary, 1915), Professor of Zoology in Victoria University, Manchester.
1864. *Hiern, W. P., M.A., F.R.S. The Castle, Barnstaple.
1914. §Higgins, J. M. Riversdale-road, Camberwell, Victoria.
1914. §Higgins, Mrs. J. M. Riversdale-road, Camberwell, Victoria.
1891. ‡Higgs, Henry, C.B., LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06.) H.M. Treasury, Whitehall, S.W.
1909. ‡Higman, Ormond. Electrical Standards Laboratory, Ottawa.
1913. *Higson, G. I., M.Sc. 11 Westbourne-road, Birkdale, Lancashire.
1907. ‡Hiley, E. V. (Local Sec. 1907.) Town Hall, Birmingham.
1911. *Hiley, Wilfrid E. Ebbor, Wells, Somerset.
1885. *Hill, Alexander, M.A., M.D. Hartley University College, Southampton.
1903. *Hill, Arthur W., M.A., F.L.S. Royal Gardens, Kew.
1906. ‡Hill, Charles A., M.A., M.B. 13 Rodney-street, Liverpool.
1881. *Hill, Rev. Edwin, M.A. The Rectory, Cockfield, Bury St. Edmunds.
1908. *Hill, James P., D.Sc., F.R.S., Professor of Zoology in University College, Gower-street, W.C.
1911. ‡Hill, Leonard, M.B., F.R.S. (Pres. I, 1912), Professor of Physiology in the University of London. Osborne House, Loughton, Essex.
1912. ‡Hill, M. D. Angelo's, Eton College, Windsor.
1886. ‡Hill, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1898. *Hill, Thomas Sidney. Langford House, Langford, near Bristol.
1907. *Hills, Major E. H., C.M.G., R.E., F.R.S., F.R.G.S. (Pres. E, 1908.) 32 Prince's-gardens, S.W.
1911. *Hills, William Frederick Waller. 32 Prince's-gardens, S.W.
1903. *Hilton, Harold. 108 Alexandra-road, South Hampstead, N.W.
1903. *Hind, Wheelton, M.D., F.G.S. Roxeth House, Stoke-on-Trent.
1870. ‡Hinde, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surr y.
1910. ‡Hindle, Edward, B.A., Ph.D., F.L.S. Quick Laboratories, Cambridge.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1898. ‡Hinds, Henry. 57 Queen-street, Ramsgate.
1911. ‡Hinks, Arthur R., M.A., F.R.S., Assist. Sec. R.G.S. Royal Geographical Society, Kensington Gore, S.W.
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
1911. ‡*Hitchcock, Miss A. M., M.A.* 40 *St. Andrew's-road, Southsea.*
1914. §Hoadley, C. A., M.Sc. Weenabah, Ballarat, Victoria.
1899. ‡Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1914. §Hobson, A. Kyme. Overseas Club, 266 Flinders-street, Melbourne.
1887. *Hobson, Bernard, M.Sc., F.G.S. Thornton, Hallamgate-road, Sheffield.
1904. ‡Hobson, Ernest William, Sc.D., F.R.S. (Pres. A, 1910), Sadlerian Professor of Pure Mathematics in the University of Cambridge. The Gables, Mount Pleasant, Cambridge.
1907. ‡Hobson, Mrs. Mary. 6 Hopefield-avenue, Belfast.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.

Year of Election.

1913. ‡Hodges, Ven. Archdeacon George, M.A. Ely.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology in the Victoria University, Manchester. 18 St. John-street, Manchester.
1880. ‡Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glenluce-road, Blackheath, S.E.
1912. ‡Hodgson, Benjamin. The University, Bristol.
1905. ‡Hodgson, Ven. Archdeacon R. The Rectory, Wolverhampton.
1909. ‡Hodgson, R. T., M.A. Collegiate Institute, Brandon, Manitoba, Canada.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1904. *Hodson, F., Ph.D. Bablake School, Coventry.
1907. ‡Hodson, Mrs. Bablake School, Coventry.
1904. ‡HOGARTH, D. G., M.A. (Pres. H, 1907 ; Council, 1907–10.) 20 St. Giles's, Oxford.
1914. §Hogben, George, M.A., F.G.S. 9 Tinakori-road, Wellington, New Zealand.
908. ‡Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.
1911. ‡Holbrook, Colonel A. R. Warleigh, Grove-road South, Southsea.
1907. ‡Holden, Colonel H. C. L., C.B., R.A., F.R.S. Gifford House, Blackheath, S.E.
1883. ‡Holden, John J. 73 Albert-road, Southport.
1887. *Holder, Henry William, M.A. Beechmount, Arnside.
1913. §Holder, Sir John C., Bart. Pitmaston, Moor Green, Birmingham.
1900. ‡HOLDICH, Colonel Sir THOMAS H., R.E., K.C.B., K.C.I.E., F.R.G.S. (Pres. E, 1902.) 41 Courtfield-road, S.W.
1887. *Holdsworth, C. J., J.P. Fernhill, Alderley Edge, Cheshire.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. ‡Holland, J. L., B.A. 3 Primrose-hill, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡HOLLAND, Sir THOMAS H., K.C.I.E., F.R.S., F.G.S. (Pres. C, 1914), Professor of Geology in the Victoria University, Manchester.
1889. ‡Holländer, Bernard, M.D. 35A Welbeck-street, W.
1906. *Hollingworth, Miss. Leithen, Newnham-road, Bedford.
1883. *Holmes, Mrs. Basil. 23 Corfton-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. Makeney, Compton-road, Winchmore Hill, N.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1912. ‡Holmes-Smith, Edward, B.Sc. Royal Botanic Gardens, Edinburgh.
1915. §HOLT, Alderman E., J.P. (LOCAL TREASURER, 1915.) Bury Old-road, Heaton Park, Manchester.
1903. *HOLT, ALFRED, M.A., D.Sc. Dowsefield, Allerton, Liverpool.
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford, D.D. Somerset Lodge, Barnet.
1908. *Hooper, Frank Henry. Deepdene, Streatham Common, S.W.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. ‡Hopewell-Smith, A., M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
1905. *Hopkins, Charles Hadley. Junior Constitutional Club, 101 Piccadilly, W.
1913. ‡HOPKINS, F. GOWLAND, M.A., D.Sc., M.B., F.R.S. (Pres. I, 1913). Trinity College, and Saxmeadham, Grange-road, Cambridge.
1901. *HOPKINSON, BERTRAM, M.A., F.R.S., F.R.S.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. 10 Adams-road, Cambridge.

Year of Election.

1884. *HOPKINSON, CHARLES. (Local Sec. 1887.) The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *HOPKINSON, JOHN, Assoc.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. Weetwood, Watford.
1905. ‡Hopkinson, Mrs. John. Ellerslie, Adams-road, Cambridge.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1910. ‡Horne, Arthur S. Kerlegh, Cobham, Surrey.
1885. ‡HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) 12 Keith-crescent, Blackhall, Midlothian.
1903. ‡Horne, William, F.G.S. Leyburn, Yorkshire.
1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, Sir VICTOR A. H., LL.D., B.Sc., F.R.S., F.R.C.S. (Council, 1893–98.) 25 Cavendish-square, W.
1908. ‡Horton, F. St. John's College, Cambridge.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Birmingham.
1908. ‡Houston, David, F.L.S. Royal College of Science, Dublin.
1893. ‡Howard, F. T., M.A., F.G.S. West Mount, Waverton, near Chester.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 56 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Holly Bank, Halifax.
1907. ‡HOWARTH, O. J. R., M.A. (ASSISTANT SECRETARY.) 24 Lansdowne-crescent, W.
1911. *HOWE, Professor G. W. O., M.Sc. 22 Dorset-road, Merton Park, Surrey.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1887. §HOYLE, WILLIAM E., M.A., D.Sc. (Pres. D, 1907.) National Museum of Wales, City Hall, Cardiff.
1903. ‡Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1913. §Huddart, Mrs. J. A. 2 Chatsworth-gardens, Eastbourne.
1898. ‡Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.
1867. *HUDSON, Professor WILLIAM H. H., M.A., LL.M. 34 Birdhurst-road, Croydon.
1913. §Hughes, Alfred, M.A., Professor of Education in the University of Birmingham. 29 George-road, Edgbaston, Birmingham.
1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland.
1914. §Hughes, Herbert W. Adelaide Club, Adelaide, South Australia.
1868. ‡HUGHES, T. M'K., M.A., F.R.S., F.G.S. (Council, 1879–86), Woodwardian Professor of Geology in the University of Cambridge. Ravensworth, Brooklands-avenue, Cambridge.

Year of Election.

1912. ‡Hukling, George. The University, Manchester.
1867. ‡Hull, Edward, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874.) 14 Stanley-gardens, Notting Hill, W.
1903. ‡Hulton, Campbell G. Palace Hotel, Southport.
1905. §Hume, D. G. W. 55 Gladstone-street, Dundee, Natal.
1911. *Hume, Dr. W. F. Helwan, Egypt.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1907. §Humphries, Albert E. Coxe's Lock Mills, Weybridge.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1881. ‡Hunter, F. W. 16 Old Elvet, Durham.
1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham.
1909. ‡Hunter, W. J. H. 31 Lynedoch-street, Glasgow.
1901. *Hunter, William. Evirallan, Stirling.
1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1913. §Hutchins, Miss B. L. The Glade, Branch Hill, Hampstead Heath, N.W.
1914. §Hutchins, D. E. Medo House, Cobham, Kent.
1894. *Hutchinson, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.
1912. §Hutchinson, Dr. H. B. Rothamsted Experimental Station, Harpenden, Herts.
1903. §Hutchinson, Rev. H. N., M.A. 17 St. John's Wood Park, Finchley-road, N.W.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1901. *Hutton, R. S., D.Sc. West-street, Sheffield.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. 5 Warwick-road, Earl's Court, S.W.

1908. ‡Idle, George. 43 Dawson-street, Dublin.
1883. ‡Idris, T. H. W. 110 Pratt-street, Camden Town, N.W.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.
1913. §Illing, Vincent Charles, B.A., F.G.S. The Chestnuts, Hartshill, Atherstone, Warwickshire.
1885. §im Thurn, Sir Everard F., C.B., K.C.M.G. (Pres. H, 1914; Council, 1913- .) 39 Lexham-gardens, W.
1907. §Ingham, Charles B. Moira House, Eastbourne.
1901. ‡Inglis, John, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1905. §Innes, R. T. A., F.R.A.S. Union Observatory, Johannesburg.
1901. *Ionides, Stephen A. 802 Equitable-building, Denver, Colorado.
1913. ‡Irvine, James, F.R.G.S. Richmond-buildings, Chapel-street, Liverpool.
1912. ‡Irvine, J. C., Ph.D., Professor of Chemistry in the University of St. Andrews.
1882. §Irving, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1908. ‡Irwin, Alderman John. 33 Rutland-square, Dublin.

1914. §Jack, A. K., B.Sc. Agricultural College, Dookie, Victoria.
1909. ‡Jacks, Professor L. P. 28 Holywell, Oxford.

Year of Election.

1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. ‡Jackson, C. S. Royal Military Academy, Woolwich, S.E.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1913. *Jackson, H. Gordon, M.Sc. Mason College, Birmingham.
1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
1898. *Jackson, Sir John. 51 Victoria-street, S.W.
1887. §Jacobson, Nathaniel, J.P. Olive Mount, Cheetham Hill-road, Manchester.
1905. *Jaffé, Arthur, M.A. New-court, Temple, E.C.
1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.
1906. ‡Jalland, W. H. Museum-street, York.
1891. *James, Charles Henry, J.P. 64 Park-place, Cardiff.
1891. *James, Charles Russell. The Bungalow, Redhill, Surrey.
1904. ‡James, Thomas Campbell. University College, Aberystwyth.
1896. *Jameson, H. Lyster, M.A., Ph.D. Borderdale, Sunningdale, Berkshire.
1889. *Japp, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898.) 36 Twyford-avenue, West Acton, W.
1910. *Japp, Henry, M.Inst.C.E. Care of Messrs. S. Pearson & Son, 507 Fifth Avenue, New York, U.S.A.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1913. ‡Jarrard, W. J. The University, Sheffield.
1903. ‡Jarratt, J. Ernest (Local Sec. 1903). 10 Cambridge-road, Southport.
1904. *Jeans, J. H., M.A., F.R.S. 8 Ormonde-gate, Chelsea, S.W.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1912. §Jehu, T. J., M.A., M.D., Professor of Geology in the University of Edinburgh.
1908. *Jenkin, Arthur Pearse, F.R.Met.Soc. Trewirgie, Redruth.
1909. *Jenkins, Miss Emily Vaughan. 31 Antrim-mansions, South Hampstead, N.W.
1903. ‡Jenkinson, J. W. The Museum, Oxford.
1904. ‡Jenkinson, W. W. 6 Moorgate-street, E.C.
1893. ‡Jennings, G. E. 60 Fosse-road South, Leicester.
1905. ‡Jennings, Sydney. P.O. Box 149, Johannesburg.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1900. *Jevons, H. Stanley, M.A., B.Sc. 3 Pembroke-terrace, Cardiff.
1907. *Jevons, Miss H. W. 17 Tredegar-square, Bow, E.
1905. §Jeyes, Miss Gertrude, B.A. Berrymead, 6 Lichfield-road, Kew Gardens.
1914. §Jobbins, G. G. Geelong Club, Geelong, Victoria.
1909. *Johns, Cosmo, F.G.S., M.I.M.E. Burngrove, Pitsmoor-road, Sheffield.
1909. ‡Johnson, C. Kelsall, F.R.G.S. The Glen, Sidmouth, Devon.
1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W., B.A., B.Sc. Archbishop Holgate's Grammar School, York.
1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.

Year of Election.

1899. ‡JOHNSTON, Colonel Sir DUNCAN A., K.C.M.G., C.B., R.E., F.R.G.S. (Pres. E, 1909.) 19 Coates-crescent, Edinburgh.
1883. ‡JOHNSTON, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. St. John's Priory, Poling, near Arundel.
1913. §Johnston, James. Oak Bank-avenue, Manchester.
1909. *Johnston, J. Weir, M.A. 129 Anglesea-road, Dublin.
1913. §Johnston, Dr. S. J. Department of Biology, The University, Sydney, N.S.W.
1908. ‡Johnston, Swift Paine. 1 Hume-street, Dublin.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1909. §JOLLY, Professor W. A., M.B., D.Sc. South African College, Cape Town.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1908), Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1887. ‡Jones, D. E., B.Sc. Eryl Dag, Radyr, Cardiff.
1913. *Jones, Daniel, M.A., Lecturer on Phonetics at University College, London, W.C.
1904. ‡Jones, Miss E. E. Constance. Girton College, Cambridge.
1890. ‡JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. ‡Jones, Evan. Ty-Mawr, Aberdare.
1907. *Jones, Mrs. Evan. 39 Hyde Park-gate, S.W.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, D.D. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1912. ‡Jones, J. H. The University, Glasgow.
1913. §Jones, O. T., M.A., D.Sc., F.G.S.. Professor of Geology in the University College of Wales. Fenton, Caradoc-road, Aberystwyth.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skyrrid, Abergavenny, Monmouthshire.
1901. ‡Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1908. ‡Jones, R. Pugh, M.A. County School, Holyhead, Anglesey.
1912. §Jones, W. Neilson. University College, Reading.
1875. *Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.
1913. ‡Jourdain, Miss Eleanor F. St. Hugh's College, Oxford.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. ‡Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.
1870. ‡JUDD, JOHN WESLEY, C.B., LL.D., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886–92.) Orford Lodge, 30 Cumberland-road, Kew.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1914. §Julius, G. A., B.Sc. Culwulla-chambers, 67 Castlereagh-street, Sydney, N.S.W.
1905. §JURITZ, CHARLES F., M.A., D.Sc., F.I.C., Chief of the Division of Chemistry, Union of South Africa. Department of Agriculture, Cape Town.

1888. ‡KAPP, GISBERT, M.Sc., M.Inst.C.E., M.Inst.E.E. (Pres. G, 1913). Professor of Electrical Engineering in the University of Birmingham. Pen-y-Coed, Pritchatts-road, Birmingham.

Year of Election.

1913. ‡Kay, Henry, F.G.S. 16 Wretham-road, Handsworth, Birmingham.
1913. ‡Kaye, G. W. C. Culver, St. James'-avenue, Hampton Hill.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡KEANE, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1913. ‡Kebby, Charles H. 75 Sterndale-road, West Kensington Park, W.
1908. §KEEBLE, FREDERICK, M.A., Sc.D., F.R.S. (Pres. K, 1912), Professor of Botany in University College, Reading.
1913. *Keeling, B. F. E. Survey Department, Giza Branch, Egypt.
1911. *Keith, Arthur, M.D., LL.D., F.R.S., F.R.C.S. Royal College of Surgeons, Lincoln's Inn-fields, W.C.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1908. ‡Kelly, Sir Malachy. Ard Brugh, Dalkey, Co. Dublin.
1908. ‡Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
1911. ‡Kelly, Miss. Montrose, Merton-road, Southsea.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898–1904.) Royal Geographical Society, Kensington Gore, S.W.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
1891. ‡KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1875. ‡KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) Athenæum Club, S.W.
1897. §Kennedy, George, M.A., LL.D., K.C. Crown Lands Department, Toronto, Canada.
1906. ‡Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E.
1908. ‡Kennedy, William. 40 Trinity College, Dublin.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1913. ‡KENRICK, W. BYNG. (Local Sec. 1913.) Metchley House, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in the University of Bristol.
1901. ‡Kent, G. 16 Premier-road, Nottingham.
1913. *Kenyon, Joseph, B.Sc., F.I.C. 51 Irving-place, Blackburn.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1881. ‡KERMODE, P. M. C. Claghbene, Ramsey, Isle of Man.
1913. §Kerr, George L. 39 Elmbank-crescent, Glasgow.
1909. ‡Kerr, Hugh L. 68 Admiral-road, Toronto, Canada.
1892. ‡KERR, J. GRAHAM, M.A., F.R.S., Regius Professor of Zoology in the University of Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1910. §Kershaw, J. B. C. West Lancashire Laboratory, Waterloo, Liverpool.
1869 *Kesselmeyer, Charles Augustus. Roseville, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Edelweiss Villa, Albert-road, Hale, Cheshire.
1903. ‡Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1902. ‡*Kidd, George. Greenhaven, Malone Park, Belfast.*
1906. ‡Kidner, Henry, F.G.S. 25 Upper Rock-gardens, Brighton.

Year of Election.

1886. §Kidston, Robert, LL.D., F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 137 West George-street, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1914. §Kiliani, R. Imperial German Consulate, Pitt-street, Sydney, N.S.W.
1896. *Killey, George Deane, J.P. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡Kimmins, C. W., M.A., D.Sc. Canon's House, St. Thomas-street, Southwark, S.E.
1875. *Kinch, Edward, F.I.C., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1914. §King, Miss Georgina. Springfield, Darlinghurst, N.S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, East Grinstead.
1883. *King, Joseph, M.P. Sandhouse, Witley, Godalming.
1908. §King, Professor L. A. L., M.A. St. Mungo's College Medical School, Glasgow.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1912. *King, W. B. R., B.A., F.G.S. Geological Survey, Jermyn-street, S.W.
1912. ‡King, W. J. Harding. 25 York House, Kensington, W.
1870. ‡King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1913. *King, William Wickham, F.G.S. Winds Point, Hagley, near Stourbridge.
1909. ‡Kingdon, A. 197 Yale-avenue, Winnipeg, Canada.
1903. ‡Kingsford, H. S., M.A. 8 Elsworthy-terrace, N.W.
1900. ‡Kipping, Professor F. Stanley, D.Sc., Ph.D., F.R.S. (Pres. B, 1908.) University College, Nottingham.
1899. *Kirby, Miss C. F. 8 Windsor-court, Moscow-road, W.
1913. §Kirkaldy, Professor A. W., M.Com. The University, Edmund-street, Birmingham.
1901. §Kitto, Edward. 2 Great Headland-terrace, Preston, Paignton, South Devon.
1914. §Knibbs, G. H., C.M.G., F.R.A.S., F.S.S. Commonwealth Bureau of Statistics, Melbourne.
1886. ‡Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1912. §Knipe, Henry R., F.L.S., F.G.S. 9 Linden-park, Tunbridge Wells.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert, J.P. Sunnybank, Wilmslow, Cheshire.
1887. *Knott, John F. Edgemoor, Burbage, Derbyshire.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. 10 Banbury-road, Wolvercote, Oxford.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1902. ‡Knox, R. Kyle, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1890. *Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.
1888 *Kunz, G. F., M.A., Ph.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.

1903. *Lafontaine, Rev. H. C. de. 52 Albert-court, Kensington Gore, S.W.
1909. ‡Laird, Hon. David. Indian Commission, Ottawa, Canada.
1904. ‡Lake, Philip. St. John's College, Cambridge.

Year of
Election.

1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1903. ‡*Lambert, Joseph. 9 Westmoreland-road, Southport.*
1893. *LAMPLUGH, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1914. §Lane, Charles. Care of John Sanderson & Co., William-street, Melbourne.
1898. *LANG, WILLIAM H., M.B., F.R.S., Professor of Cryptogamic Botany in the University of Manchester. 2 Heaton-road, Withington, Manchester.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904–07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.
1865. ‡LANKESTER, Sir E. RAY, K.C.B., M.A., LL.D., D.Sc., F.R.S. (PRESIDENT, 1906; Pres. D, 1883; Council, 1889–90, 1894–95, 1900–02.) 331 Upper Richmond-road, Putney, S W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Dimsdale, 4 Pond-road, Blackheath Park, London, S.E.
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1911. ‡Lapthorn, Miss. St. Bernard's, Grove-road South, Southsea.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892.) 38 Calthorpe-road, Edgbaston, Birmingham.
1909. ‡Larard, C. E., Assoc.M.Inst.C.E. 14 Leaside-avenue, Muswell Hill, N.
1887. ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.
1881. ‡LARMOR, Sir JOSEPH, M.A., D.Sc., F.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. ‡Lascelles, B. P., M.A. Headland, Mount Park, Harrow.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. Parliament-mansions, Westminster, S.W.
1911. §Lattey, R. T. 243 Woodstock-road, Oxford.
1900. ‡Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1911. §Laurie, Miss C. L. 1 Vittoria-walk, Cheltenham.
1913. *Laurie, Mrs. E. B. 11 Marine-parade, Hoylake.
1892. ‡LAURIE, MALCOLM, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1907. *Laurie, Robert Douglas, M.A. Department of Zoology, The University, Liverpool.
1870. *Law, Channell. Ilsham Dene, Torquay.
1905. ‡Lawrence, Miss M. Roedean School, near Brighton.
1911. *Lawson, A. Anstruther, D.Sc., F.R.S.E., F.L.S., Professor of Botany in the University, Sydney, N.S.W.
1908. ‡Lawson, H. S., B.A. Buxton College, Derbyshire.
1908. ‡Lawson, William, LL.D. 27 Upper Fitzwilliam-street, Dublin.
1914. §Layard, J. W. King's College, Cambridge.
1888. ‡Layard, Miss Nina F., F.L.S. Rookwood, Fonnereau-road, Ipswich.
1913. §Lea, F. C., D.Sc. 36 Mayfield-road, Moseley, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1914. §Leach, T. H. de Blois. Yardley Lodge, Crick-road, Oxford.
1894. *LEAHY, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.

Year of
Election.

1905. ‡Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, George, B.Sc. 3 Park-quadrant, Glasgow.
1904. *Leathem, J. G. St. John's College, Cambridge.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., D.Sc., Professor of Geology in the Armstrong College of Science, Newcastle-on-Tyne.
1910. §Lebour, Miss M. V., M.Sc. Zoological Department, The University, Leeds.
1912. §Lechmere, A. Eckley, M.Sc. Townhope, Hereford.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1914. §Lee, Charles Alfred. Tenterfield, N.S.W.
1910. *Lee, Ernest. Birkbeck College, Chancery-lane, E.C.
1896. §Lee, Rev. H. J. Barton. 126 Mile End-lane, Stockport.
1907. ‡Lee, Mrs. Barton. 126 Mile End-lane, Stockport.
1909. §Lee, I. L. 26 Broadway, New York City, U.S.A.
1909. ‡Lee, Rev. J. W., D.D. 5068 Washington-avenue, St. Louis, Missouri, U.S.A.
1894. *Lee, Mrs. W. The Nook, Forest Row, Sussex.
1909. ‡Leeming, J. H., M.D. 406 Devon-court, Winnipeg, Canada.
1905. ‡*Lees, Mrs. A. P. Care of Dr. Norris Wolfenden,* 76 *Wimpole-street, W.*
1892. *LEES, CHARLES H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End. Greenacres, Woodside-road, Woodford Green, Essex.
1912. ‡Lees, John. Pitscottie, Cupar-Fife, N.B.
1886. *Lees, Lawrence W. Lynstone, Barnt Green.
1906. ‡Lees, Robert. Victoria-street, Fraserburgh.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1906 ‡Leetham, Sidney. Elm Bank, York.
1912. ‡LEGGAT, W. G. Bank of Scotland, Dundee.
1912. ‡Legge, James G. Municipal Buildings, Liverpool.
1910. §Leigh, H. S. Brentwood, Worsley, near Manchester.
1891. ‡Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.
1903. ‡Leighton, G. R., M.D., F.R.S.E. Local Government Board, Edinburgh.
1906. ‡Leiper, Robert T., M.B., F.Z.S. London School of Tropical Medicine, Royal Albert Dock, E.
1905. ‡Leitch, Donald. P.O. Box 1703, Johannesburg.
1913. §Leith, Professor R. F. C. Pathological Laboratory, The University, Birmingham.
1903. *Lempfert, R. G. K., M.A. 66 Sydney-street, S.W.
1908. ‡Lentaigne, John. 42 Merrion-square, Dublin.
1887. *Leon, John T., M.D., B.Sc. 23 Grove-road, Southsea.
1901. §LEONARD, J. H., B.Sc. 31 Gunterstone-road, West Kensington, W.
1914. §Le Souef, W. H. D., C.M.Z.S. Zoological Gardens, Parkville, Victoria.
1913. ‡Lessing, R., Ph.D. 317 High Holborn, W.C.
1912. *Lessner, C. B., Assoc.M.Inst.C.E., F.C.S. Carril, Spain.
1890. *Lester, Joseph Henry. 5 Grange-drive, Monton Green, Manchester.
1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E.
1900. ‡Letts, Professor E. A., D.Sc., F.R.S.E. Queen's University, Belfast.
1896. ‡Lever, Sir W. H., Bart. Thornton Manor, Thornton Hough, Cheshire.

Year of Election.

1913. §Levick, John. Livingstone House, Livingstone-road, Handsworth, Birmingham.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1893. *LEWES, VIVIAN B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1904. *Lewis, Mrs. Agnes S., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1870. ‡LEWIS, ALFRED LIONEL. 35 Beddington-gardens, Wallington, Surrey.
1891. ‡Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1913. §Lewis, E. O. Gwynfa, Alma-street, Brynmawr.
1899. ‡Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1910. §LEWIS, FRANCIS J., D.Sc., F.L.S., Professor of Biology in the University of Alberta, Edmonton, Alberta, Canada.
1904. ‡Lewis, Hugh. Glanafrau, Newtown, Montgomeryshire.
1910. *Lewis, T. C. West Home, West-road, Cambridge.
1911. §Lewis, W. C. McC., M.A., D.Sc., Professor of Physical Chemistry in the University of Liverpool.
1906. ‡Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.
1913. *Lillie, D. G. St. John's College, Cambridge.
1908. ‡Lilly, W. E., M.A., Sc.D. 39 Trinity College, Dublin.
1904. ‡Link, Charles W. 14 Chichester-road, Croydon.
1898. ‡Lippincott, R. C. Cann. Over Court, near Bristol.
1913. *Lishman, G. P., D.Sc., F.I.C. Chemical Laboratory, Lambton Coke Works, Fence Houses, Co. Durham.
1888. ‡LISTER, J. J., M.A., F.R.S. (Pres. D, 1906.) St. John's College, Cambridge.
1861. *LIVEING, G. D., M.A., F.R.S. (Pres. B, 1882; Council, 1888–95; Local Sec. 1862.) Newnham, Cambridge.
1876. *LIVERSIDGE, ARCHIBALD, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S. Fieldhead, George-road, Kingston Hill, Surrey.
1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1912. §Lloyd, Miss Dorothy Jordan. 16 Ampton-road, Edgbaston, Birmingham.
1909. §Lloyd, George C., Secretary of the Iron and Steel Institute. 28 Victoria-street, S.W.
1903. ‡Lloyd, Godfrey I. H. The University of Toronto, Canada.
1892. ‡LOCH, C. S., D.C.L. Denison House, Vauxhall Bridge-road, S.W.
1905. ‡Lochrane, Miss T. 8 Prince's-gardens, Dowanhill, Glasgow.
1904. ‡Lock, Rev. J. B. Herschel House, Cambridge.
1863. ‡LOCKYER, Sir J. NORMAN, K.C.B., LL.D., D.Sc., F.R.S. (PRESIDENT, 1903; Council, 1871–76, 1901–02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1914. §Lockyer, Ormonde H. S. 126 Webster-street, Ballarat, Victoria.
1900. §LOCKYER, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *LODGE, ALFRED, M.A. (Council, 1913– .) The Croft, Peperharow-road, Godalming.
1914. §Lodge, Miss Lorna L. Mariemont, Edgbaston, Birmingham.
1914. §Lodge, Miss Norah M. Mariemont, Edgbaston, Birmingham.
1875. *LODGE, Sir OLIVER J., D.Sc., LL.D., F.R.S. (PRESIDENT, 1913; Pres. A, 1891; Council, 1891–97, 1899–1903, 1912–13), Principal of the University of Birmingham.
1914. §Lodge, Lady. Mariemont, Edgbaston, Birmingham.
1894. *Lodge, Oliver W. F. Mariemont, Edgbaston, Birmingham.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1903. ‡Long, Frederick. The Close, Norwich.

Year of Election.

1905. ‡Long, W. F. City Engineer's Office, Cape Town.
1883. *Long, William. Thelwall Heys, near Warrington.
1910. *Longden, G. A. Stanton-by-Dale, Nottingham.
1904. *Longden, J. A., M.Inst.C.E. Chislehurst, Marlborough-road, Bournemouth.
1898. *Longfield, Miss Gertrude. Belmont, High Halstow, Rochester.
1901. *Longstaff, Captain Frederick V., F.R.G.S. No. 1252 Post Office, Victoria, B.C., Canada.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W.
1899. *Longstaff, Tom G., M.A., M.D. Picket Hill, Ringwood.
1903. ‡*Loton, John, M.A. 23 Hawkshead-street, Southport.*
1897. ‡LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *LOUIS, D. A., F.G.S., F.I.C. 123 Pall Mall, S.W.
1896 ‡Louis, Henry, D.Sc., Professor of Mining in the Armstrong College of Science, Newcastle-on-Tyne.
1887. *LOVE, A. E. H., M.A., D.Sc., F.R.S. (Pres. A, 1907), Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. *Love, E. F. J., M.A., D.Sc. The University, Melbourne, Australia.
1904. *Love, J. B., LL.D. Outlands, Devonport.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1908. §Low, Alexander, M.A., M.D. The University, Aberdeen.
1909. ‡Low, David, M.D. 1927 Scarth-street, Regina, Saskatchewan, Canada.
1912. ‡Low, William. Balmakewan, Seaview, Monifieth.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Spondon, Derbyshire.
1894. ‡Lowenthal, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. *LOWRY, Dr. T. MARTIN, F.R.S. 130 Horseferry-road, S.W.
1913. §LUCAS, Sir CHARLES P., K.C.B., K.C.M.G. (Pres. E, 1914.) 65 St. George's-square, S.W.
1913. §Lucas, Harry. Hilver, St. Agnes-road, Moseley, Birmingham.
1901. *Lucas, Keith, F.R.S. Trinity College, Cambridge.
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1906. ‡Ludlam, Ernest Bowman. College Gate, 32 College-road, Clifton, Bristol.
1866. *Lund, Charles. Ilkley, Yorkshire.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S. 7 Victoria-street, S.W.
1914. §Lupton, Mrs. 7 Victoria-street, S.W.
1874. *LUPTON, SYDNEY, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1898. ‡Luxmoore, Dr. C. M., F.I.C., 19 Disraeli-gardens, Putney, S.W.
1903. ‡Lyddon, Ernest H. Lisvane, near Cardiff.
1871. ‡Lyell, Sir Leonard, Bart., F.G.S. Kinnordy, Kirriemuir.
1914. §LYLE, Professor T. R., M.A., F.R.S. Irving-road, Toorak, Victoria.
1884 ‡Lyman, H. H. 384 St. Paul-street, Montreal, Canada.
1912. *Lynch, Arthur, M.A., M.P. 80 Antrim-mansions, Haverstock Hill, N.W.
1907. *LYONS, Captain HENRY GEORGE, D.Sc., F.R.S. (Council, 1912– .) 3 Durham-place, Chelsea, S.W.

Year of Election.

1908. ‡Lyster, George H. 34 Dawson-street, Dublin.
1908. ‡Lyster, Thomas W., M.A. National Library of Ireland, Kildare-street, Dublin.

1905. ‡Maberly, Dr. John. Shirley House, Woodstock, Cape Colony.
1868. ‡MACALISTER, ALEXANDER, M.A., M.D., F.R.S. (Pres. H, 1892; Council, 1901–06), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, Sir DONALD, K.C.B., M.A., M.D., LL.D., B.Sc., Principal of the University of Glasgow.
1904. ‡Macalister, Miss M. A. M. Torrisdale, Cambridge.
1896. ‡MACALLUM, Professor A. B., Ph.D., D.Sc., F.R.S. (Pres. I, 1910; Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1914. §McAlpine, D. Berkeley-street, Hawthorn, Victoria.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1909. ‡MacArthur, J. A., M.D. Canada Life Building, Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. The Chesters, Vicarage-road, East Sheen, S.W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. ‡MACBRIDE, E. W., M.A., D.Sc., F.R.S., Professor of Zoology in the Imperial College of Science and Technology, S.W.
1902. *Maccall, W. T., M.Sc. Technical College, Sunderland.
1912. ‡McCallum, George Fisher. 142 St. Vincent-street, Glasgow.
1912. ‡McCallum, Mrs. Lizzie. 142 St. Vincent-street, Glasgow.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 50 Harborne-road, Edgbaston, Birmingham.
1908. §McCarthy, Edward Valentine, J.P. Ardmanagh House, Glenbrook, Co. Cork.
1909. ‡McCarthy, J. H. Public Library, Winnipeg, Canada.
1884. *McCarthy, J. J., M.D. 11 Wellington-road, Dublin.
1887. *McCarthy, James. 1 Sydney-place, Bath.
1904. §McClean, Frank Kennedy. Rusthall House, Tunbridge Wells.
1902. ‡McClelland, J. A., M.A., F.R.S., Professor of Physics in University College, Dublin.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W.
1914. §McColl, Miss Ada. Post Office, Parkville, Victoria.
1878. *M'Comas, Henry. 12 Elgin-road, Dublin.
1908. §MCCOMBIE, HAMILTON, M.A., Ph.D. The University, Birmingham.
1914. §McCombie, Mrs. Hamilton. The University, Birmingham.
1901. *MacConkey, Alfred. Lister Lodge, Elstree, Herts.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1912. ‡MacCulloch, Rev. Canon J. A., D.D. The Rectory, Bridge of Allan.
1905. §McCulloch, Principal J. D. Free College, Edinburgh.
1904. ‡McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1909. ‡MacDonald, Miss Eleanor. Fort Qu'Appelle, Saskatchewan, Canada.
1904. ‡MACDONALD, H. M., M.A., F.R.S., Professor of Mathematics in the University of Aberdeen.
1905. ‡McDonald, J. G. P.O. Box 67, Bulawayo.
1900. ‡MacDonald, J. Ramsay, M.P. 3 Lincoln's Inn-fields, W.C.
1905. ‡MACDONALD, J. S., B.A. (Pres. I, 1911), Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W. C. 449 Sherbrooke-street West, Montreal, Canada.
1909. ‡MacDonell, John, M.D. Portage-avenue, Winnipeg, Canada.
1909. *MacDougall, R. Stewart. The University, Edinburgh.
1912. ‡McDougall, Dr. W., F.R.S. Woodsend, Foxcombe Hill, near Oxford.

Year of Election.
1908. ‡McEwen, Walter, J.P. Flowerbank, Newton Stewart, Scotland.
1906. §McFarlane, John, M.A. 48 Parsonage-road, Withington, Manchester.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania. Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1901. ‡Macfee, John. 5 Greenlaw-terrace, Paisley.
1909. ‡Macgachen, A. F. D. 281 River-avenue, Winnipeg, Canada.
1888. ‡MacGeorge, James. 8 Matheson-road, Kensington, W.
1908. ‡McGrath, Sir Joseph, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1908. ‡McGregor, Charles. Training Centre, Charlotte-street, Aberdeen.
1906. ‡Maccregor, D. H., M.A. Trinity College, Cambridge.
1902. ‡*McIlroy, Archibald. Glenvale, Drumbo, Lisburn, Ireland.*
1867. *McIntosh, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1909. ‡McIntyre, Alexander. 142 Maryland-avenue, Winnipeg, Canada.
1909. ‡McIntyre, Daniel. School Board Offices, Winnipeg, Canada.
1912. ‡McIntyre, J. Lewis, M.A., D.Sc. Abbotsville, Cults, Aberdeenshire.
1909. ‡McIntyre, W. A. 339 Kennedy-street, Winnipeg, Canada.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1913. *Mackay, John. 85 Bay-street, Toronto, Canada.
1885. ‡Mackay, John Yule, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1912. §Mackay, R. J. 27 Arkwright-road, Hampstead, N.W.
1908. ‡McKay, William, J.P. Clifford-chambers, York.
1909. §McKee, Dr. E. S. Sinton and Nassau-streets, Cincinnati, U.S.A.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903–09), Emeritus Professor of Physiology in the University of Glasgow. Maxieburn, Stonehaven, N.B.
1909. ‡McKenty, D. E. 104 Colony-street, Winnipeg, Canada.
1907. ‡McKenzie, Alexander, M.A., D.Sc., Ph.D. Birkbeck College, Chancery-lane, W.C.
1905. ‡Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1910. ‡Mackenzie, K. J. J., M.A. 10 Richmond-road, Cambridge.
1909. §MacKenzie, Kenneth. Royal Alexandra Hotel, Winnipeg, Canada.
1901. *Mackenzie, Thomas Brown. Netherby, Manse-road, Motherwell, N.B.
1912. §Mackenzie, William, J.P. 22 Meadowside, Dundee.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡Mackinder, H. J., M.A., M.P., F.R.G.S. (Pres. E, 1895; Council, 1904–05.) 25 Cadogan-gardens, S.W.
1911. ‡Mackinnon, Miss D. L. University College, Dundee.
1893. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 137 Tettenhall-road, Wolverhampton.
1901. *Maclaren, J. Malcolm. Royal Colonial Institute, Northumberland Avenue, W.C.
1913. §McLaren, S. B. University College, Reading.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. ‡McLean, Angus, B.Sc. Harvale, Meikleriggs, Paisley.
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1912. §McLean, R. C., B.Sc. Duart, Holmes-road, Reading.

Year of Election.

1908. §McLennan, J. C., Professor of Physics in the University of Toronto, Canada.
1868. §McLeod, Herbert, LL.D., F.R.S. (Pres. B, 1892; Council, 1885–90.) 37 Montague-road, Richmond, Surrey.
1909. ‡MacLeod, M. H. C.N.R. Depôt, Winnipeg, Canada.
1883. ‡MacMahon, Major Percy A., D.Sc., LL.D., F.R.S. (Trustee, 1913– ; General Secretary, 1902–13; Pres. A, 1901; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, S.W.
1909. ‡McMillan, The Hon. Sir Daniel H., K.C.M.G. Government House, Winnipeg, Canada.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1914. §Macnicol, A. N. 31 Queen-street, Melbourne.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, Dr. S. Rutherford. Rowditch, Derby.
1909. ‡MacPhail, W. M. P.O. Box 88, Winnipeg, Canada.
1907. ‡Macrosty, Henry W. 29 Hervey-road, Blackheath, S.E.
1906. ‡Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1908. ‡McVittie, R. B., M.D. 62 Fitzwilliam-square North, Dublin.
1908. ‡McWalter, J. C., M.D., M.A. 19 North Earl-street, Dublin.
1902. ‡McWeeney, Professor E. J., M.D. 84 St. Stephen's-green, Dublin.
1910. ‡McWilliam, Dr. Andrew. Kalimate, B.N.R., near Calcutta.
1908. ‡Madden, Rt. Hon. Mr. Justice. Nutley, Booterstown, Dublin.
1905. ‡Magenis, Lady Louisa. 34 Lennox-gardens, S.W.
1909. ‡Magnus, Laurie, M.A. 12 Westbourne-terrace, W.
1875. *Magnus, Sir Philip, B.Sc., B.A., M.P. (Pres. L, 1907.) 16 Gloucester-terrace, Hyde Park, W.
1908. *Magson, Egbert H. Westminster College, Horseferry-road, S.W.
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W.
1902. *Mairet, Mrs. Ethel M. The Thatched House, Shottery, Stratford-on-Avon.
1914. §Maitland, A. Gibb. Geological Survey, Perth, Western Australia.
1913. ‡Maitland, T. Gwynne, M.D. The University, Edmund-street, Birmingham.
1908. *Makower, W. The University, Manchester.
1914. §Malinowski, B. London School of Economics, Clare Market, W.C.
1912. ‡Malloch, James, M.A., F.S.A. (Scot.) Training College, Dundee.
1905. ‡Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.
1897. ‡Mance, Sir H. C. Old Woodbury, Sandy, Bedfordshire.
1903. ‡Manifold, C. C. 16 St. James's-square, S.W.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1902. *Marchant, Dr. E. W. The University, Liverpool.
1912. §Marchant, Rev. James, F.R.S.E. 42 Great Russell-street, W.C.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1911. *Marett, R. R., D.Sc. Exeter College, Oxford.
1900. ‡Margerison, Samuel. Calverley Lodge, near Leeds.
1864. ‡Markham, Sir Clements R., K.C.B., F.R.S., F.R.G.S., F.S.A. (Pres. E, 1879; Council, 1893–96.) 21 Eccleston-square, S.W.
1905. §Marks, Samuel. P.O. Box 379, Pretoria.
1905. ‡Marloth, R., M.A., Ph.D. P.O. Box 359, Cape Town.
1881. *Marr, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council, 1896–1902, 1910–14.) St. John's College, Cambridge.
1903. ‡Marriott, William. Royal Meteorological Society, 70 Victoria-street, S.W.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.

Year of Election.

1883. *Marsh, Henry Carpenter. 3 Lower James-street, Golden-square, W.

1887. ‡Marsh, J. E., M.A., F.R.S. University Museum, Oxford.

1889. *MARSHALL, ALFRED, M.A., LL.D., D.Sc. (Pres. F, 1890.) Balliol Croft, Madingley-road, Cambridge.

1912. ‡Marshall, Professor C. R., M.A., M.D. The Medical School, Dundee.

1904. ‡Marshall, F. H. A. University of Edinburgh.

1905. ‡Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W.

1901. ‡*Marshall, Robert. 97 Wellington-street, Glasgow.*

1907. ‡Marston, Robert. 14 Ashleigh-road, Leicester.

1899. ‡Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.

1911. §MARTIN, Professor CHARLES JAMES, M.B., D.Sc., F.R.S., Director of the Lister Institute, Chelsea-gardens, S.W.

1884. §Martin, N. H., J.P., F.R.S.E., F.L.S. Ravenswood, Low Fell, Gateshead.

1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Windermere, Mount Pleasant-road, Hastings.

1912. ‡MARTIN, W. H. BLYTH. (Local Sec. 1912.) City Chambers, Dundee.

1911. §Martindell, E. W., M.A. Royal Anthropological Institute, 50 Great Russell-street, W.C.

1913. ‡MARTINEAU, Lieut.-Colonel ERNEST, V.D. Ellerslie, Augustus-road, Edgbaston, Birmingham.

1913. §Martineau, P. E. The White House, Wake Green-road, Moseley, Birmingham.

1907. ‡Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.

1905. *Mason, Justice A. W. Supreme Court, Pretoria.

1913. *Mason, Edmund W., B.A. 2 York-road, Edgbaston, Birmingham.

1893. *Mason, Thomas. Enderleigh, Alexandra Park, Nottingham.

1913. ‡Mason, William. Engineering Laboratory, The University, Liverpool.

1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.

1885. §MASSON, DAVID ORME, D.Sc., F.R.S., Professor of Chemistry in the University of Melbourne.

1910. ‡Masson, Irvine, M.Sc. University College, W.C.

1905. §Massy, Miss Mary. 2 Duke-street, Bath.

1901. *Mather, G. R. Boxlea, Wellingborough.

1910. *Mather, Thomas, F.R.S., Professor of Electrical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.

1887. *Mather, Right Hon. Sir William, M.Inst.C.E. Salford Iron Works, Manchester.

1909. ‡Mathers, Mr. Justice. 16 Edmonton-street, Winnipeg, Canada.

1913. §Matheson, Miss M. Cecile. Birmingham Women's Settlement, 318 Summer-lane, Birmingham.

1908. ‡Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.

1894. ‡MATHEWS, G. B., M.A., F.R.S. 10 Menai View, Bangor, North Wales.

1902. ‡MATLEY, C. A., D.Sc. Military Accounts Department, Naina Tal, U.P., India.

1904. ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.

1899. *Maufe, Herbert B., B.A., F.G.S. P.O. Box 168, Bulawayo, Rhodesia.

1914. §Maughan, M. M., B.A., Director of Education. Parkside, South Australia.

Year of
Election.

1893. ‡Mavor, Professor James. University of Toronto, Canada.
1894. §Maxim, Sir Hiram S. Thurlow Park, Norwood-road, West Norwood, S.E.
1905. *Maylard, A. Ernest. 12 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 12 Blythswood-square, Glasgow.
1878. *Mayne, Thomas. 19 Lord Edward-street, Dublin.
1904. ‡Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1912. §Meek, Alexander, M.Sc., Professor of Zoology in the Armstrong College of Science, Newcastle-on-Tyne.
1913. §Megson, A. L. The Elms, Vale-road, Bowdon.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1905. ‡Mein, W. W. P.O. Box 1145, Johannesburg.
1881. *Meldola, Raphael, D.Sc., LL.D., F.R.S., F.C.S., F.I.C., F.R.A.S., F.E.S., Officier de l'Instr. Publ. France (Pres. B, 1895; Council, 1892–99, 1911–), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1908. ‡Meldrum, A. N., D.Sc. Chemical Department, The University, Manchester.
1883. ‡Mellis, Rev. James. 23 Part-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1881. §Melrose, James. Clifton Croft, York.
1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Val, Standerton District, Transvaal.
1901. ‡Mennell, F. P., F.G.S. 49 London Wall, E.C.
1913. *Mentz-Tolley, Richard. Moseley Court, near Wolverhampton.
1909. ‡Menzies, Rev. James, M.D. Hwaichingfu, Honan, China.
1914. §Meredith, Mrs. C. M. 55 Bryansburn-road, Bangor, Co. Down.
1905. ‡Meredith, H. O., M.A., Professor of Economics in Queen's University, Belfast. 55 Bryansburn-road, Bangor, Co. Down.
1879. ‡Merivale, John Herman, M.A. (Local Sec. 1889.) Togston Hall, Acklington.
1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Wallington, Surrey.
1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1914. §Messent, A. E. The Observatory, Adelaide, South Australia.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.
1896. §Metzler, W. H., Ph.D., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡Miall, Louis C., D.Sc., F.R.S., F.L.S., F.G.S. (Pres. D, 1897, Pres. L, 1908; Local Sec. 1890.) Norton Way North, Letchworth.
1903. *Mickleth wait, Miss Frances M. G. 15 St. Mary's-square, Paddington, W.
1912. §Middlemore, Thomas, B.A. Melsetter, Orkney.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Bishop's House, Middlesbrough.
1904. ‡Middleton, T. H., C.B., M.A. (Pres. M, 1912.) Board of Agriculture and Fisheries, 4 Whitehall-place, S.W.
1894. *Miers, Sir H. A., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1905; Pres. L, 1910), Principal of the University of London. 23 Wetherby-gardens, S.W.
1885. ‡Mill, Hugh Robert, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W.
1905. ‡Mill, Mrs. H. R. 62 Camden-square, N.W.

Year of Election.

1912. ‡MILLAR, Dr. A. H. (Local Sec. 1912.) Albert Institute, Dundee.
1889. *MILLAR, ROBERT COCKBURN. 30 York-place, Edinburgh.
1909. §Miller, A. P. Glen Miller, Ontario, Canada.
1897. *Miller, G. Willet, Provincial Geologist. Provincial Geologist's Office, Toronto, Canada.
1895. ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1904. ‡Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. ‡Mills, Mrs. A. A. Ceylon Villa, Blinco-grove, Cambridge.
1908. ‡Mills, Miss E. A. Nurney, Glenagarey, Co. Dublin.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W.
1908. §Mills, John Arthur, M.B. Durham County Asylum, Winterton, Ferryhill.
1908. §Mills, W. H., M.Inst.C.E. Nurney, Glenagarey, Co. Dublin.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1907. ‡Milne, A., M.A. University School, Hastings.
1910. §Milne, J. B. Cross Grove House, Totley, near Sheffield.
1910. *Milne, James Robert, D.Sc., F.R.S.E. 11 Melville-crescent, Edinburgh.
1903. *Milne, R. M. Royal Naval College, Dartmouth, South Devon.
1898. *MILNER, S. ROSLINGTON, D.Sc. The University, Sheffield.
1908. §Milroy, T. H., M.D., Dunville Professor of Physiology in Queen's University, Belfast.
1907. §MILTON, J. H., F.G.S., F.L.S., F.R.G.S. 8 College-avenue, Crosby, Liverpool.
1912. §Minchin, E. A., M.A., F.R.S., Professor of Protozoology in the University of London. 53 Cheyne-court, Chelsea, S.W.
1914. §Minchin, Mrs. 53 Cheyne-court, Chelsea, S.W.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1913. *Mitchell, Francis W. V. 25 Augustus-road, Edgbaston, Birmingham.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1909. ‡Mitchell, J. F. 211 Rupert-street, Winnipeg, Canada.
1885. ‡MITCHELL, P. CHALMERS, M.A., D.Sc., F.R.S., Sec.Z.S. (Pres. D, 1912; Council, 1906–13.) Zoological Society, Regent's Park, N.W.
1905. *Mitchell, W. E. C. Box 129, Johannesburg.
1908. ‡Mitchell, W. M. 2 St. Stephen's Green, Dublin.
1914. §Mitchell, William, M.A., D.Sc., Hughes Professor of Philosophy and Economics in the University of Adelaide, South Australia.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1908. ‡Moffat, C. B. 36 Hardwicke-street, Dublin.
1905. ‡Moir, James, D.Sc. Mines Department, Johannesburg.
1905. §Molengraaff, Professor G. A. F. Voorstreat 60, Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1900. *MONCKTON, H. W., Treas. L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C.
1905. *MONCRIEFF, Colonel Sir C. SCOTT, G.C.S.I., K.C.M.G., R.E. (Pres. G, 1905.) 11 Cheyne-walk, S.W.
1905. ‡Moncrieff, Lady Scott. 11 Cheyne-walk, S.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1909. ‡Moody, A. W., M.D. 432½ Main-street, Winnipeg, Canada.
1909. *MOODY, G. T., D.Sc. Lorne House, Dulwich, S.E.

Year of Election.

1914. §Moody, Mrs. Lorne House, Dulwich, S.E.
1912. §MOORE, BENJAMIN, D.Sc., F.R.S. (Pres. I, 1914.) 84 Shrewsbury-road, Birkenhead.
1911. §Moore, E. S., Professor of Geology and Mineralogy in the School of Mines, Pennsylvania State College, Pennsylvania, U.S.A.
1908. *MOORE, Sir F. W. Royal Botanic Gardens, Glasnevin, Dublin.
1894. ‡Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1908. ‡Moore, Sir John W., M.D. 40 Fitzwilliam-square West, Dublin.
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1905. ‡Moore, T. H. Thornhill Villa, Marsh, Huddersfield.
1892. ‡Moray, The Right Hon. the Earl of, F.G.S. Kinfauns Castle, Perth.
1912. ‡Moray, The Countess of. Kinfauns Castle, Perth.
1896. *MORDEY, W. M. 82 Victoria-street, S.W.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1905. *Morgan, Miss Annie. Care of London County and Westminster Bank, Chancery-lane, W.C.
1895. ‡MORGAN, C. LLOYD, F.R.S., F.G.S., Professor of Psychology in the University of Bristol.
1902. ‡MORGAN, GILBERT T., D.Sc., F.I.C., Professor of Chemistry in the Royal College of Science, Dublin.
1902. *Morgan, Septimus Vaughan. 37 Harrington-gardens, S.W.
1901. *Morison, James. Perth.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 5 Lyndhurst-road, Hampstead, N.W.
1906. ‡Morrell, H. R. Scarcroft-road, York.
1896. *Morrell, Dr. R. S. Tor Lodge, Tettenhall Wood, Wolverhampton.
1892. ‡MORRIS, Sir DANIEL, K.C.M.G., D.Sc., F.L.S. 14 Crabton-close, Boscombe, Hants.
1896. *Morris, J. T. 36 Cumberland-mansions, Seymour-place, W.
1880. §Morris, James. 23 Brynymor-crescent, Swansea.
1907. ‡Morris, Colonel Sir W. G., K.C.M.G. Care of Messrs. Cox & Co, 16 Charing Cross, W.C.
1899. *MORROW, JOHN, M.Sc., D.Eng. Armstrong College, Newcastle-upon-Tyne.
1909. ‡Morse, Morton F. Wellington-crescent, Winnipeg, Canada.
1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
1896. *MORTON, WILLIAM B., M.A., Professor of Natural Philosophy in Queen's University, Belfast.
1883. ‡Moseley, Mrs. 48 Woodstock-road, Oxford.
1913. *Moseley, Henry Gwyn-Jeffreys. 48 Woodstock-road, Oxford.
1913. §Mosely, Alfred. West Lodge, Barnet.
1908. ‡Moss, Dr. C. E. Botany School, Cambridge.
1912. ‡Moss, Mrs. 154 Chesterton-road, Cambridge.
1876. §Moss, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1892. *Mostyn, S. G., M.A., M.B. Health Office, Houndgate, Darlington.
1913. ‡Mott, Dr. F. W., F.R.S. 25 Nottingham-place, W.
1913. ‡Mottram, V. H. 256 Lordship-lane, East Dulwich, S.E.
1912. *Moulton, J. C. Sarawak Museum, Sarawak.
1878. *MOULTON, The Right Hon. Lord Justice, M.A., K.C., F.R.S. 57 Onslow-square, S.W.
1899 ‡Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1905. ‡Moylan, Miss V. C. 3 Canning-place, Palace Gate, W.
1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
1911. *Moysey, Lewis, B.A., M.B. St. Moritz, Ilkeston-road, Nottingham.
1912. ‡Mudie, Robert Francis. 6 Fintry-place, Broughty Ferry.

Year of Election.

1902. §Muir, Arthur H. 7 Donegall-square West, Belfast.
1907. *Muir, Professor James. 31 Burnbank-gardens, Glasgow.
1874. ‡MUIR, M. M. PATTISON, M.A. Hillcrest, Farnham, Surrey.
1909. ‡Muir, Robert R. Grain Exchange-building, Winnipeg, Canada.
1912. §Muir, Thomas Scott. 19 Seton-place, Edinburgh.
1904. ‡Muir, William, I.S.O. Rowallan, Newton Stewart, N.B.
1872. *MUIRHEAD, ALEXANDER, D.Sc., F.R.S., F.C.S. 12 Carteret-street, Queen Anne's Gate, Westminster, S.W.
1913. §Muirhead, Professor J. H. The Rowans, Balsall Common, near Coventry.
1905. *Muirhead, James M. P., F.R.S.E. Dunlop Rubber Co., 3 Wallace-street, Bombay.
1876. *Muirhead, Robert Franklin, B.A., D.Sc. 64 Great George-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1904. ‡Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.
1911. ‡Mumby, Dr. B. H. Borough Asylum, Milton, Portsmouth.
1898. ‡Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
1901. *Munby, Alan E. 44 Downshire-hill, Hampstead, N.W.
1906. ‡Munby, Frederick J. Whixley, York.
1904. ‡Munro, A. Queen's College, Cambridge.
1909. ‡Munro, George. 188 Roslyn-road, Winnipeg, Canada.
1883. *MUNRO, ROBERT, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1909. ‡Munson, J. H., K.C. Wellington-crescent, Winnipeg, Canada.
1914. *Murchison, Roderick. Melbourne-mansions, Collins-street, Melbourne.
1911. ‡*Murdoch, W. H. F., B.Sc.* 14 *Howitt-road, Hampstead, N.W.*
1909. §Murphy, A. J. Vanguard Manufacturing Co., Dorrington-street, Leeds.
1908. ‡Murphy, Leonard. 156 Richmond-road, Dublin.
1908. ‡MURPHY, WILLIAM M., J.P. Dartry, Dublin.
1905. ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1903. §Murray, Colonel J. D. Rowbottom-square, Wigan.
1905. §Murray, Sir James, LL.D., Litt.D. Sunnyside, Oxford.
1905. §Murray, Lady. Sunnyside, Oxford.
1914. §Murray, John. Tullibardin New Farm, Brisbane, Australia.
1892. ‡Murray, T. S., D.Sc. 27 Shamrock-street, Dundee.
1909. ‡Murray, W. C. University of Saskatchewan, Saskatoon. Saskatchewan, Canada.
1906. ‡Musgrove, Mrs. Edith M. S., D.Sc. The Woodlands, Silverdale, Lancashire.
1912. *Musgrove, James, M.D., Professor of Anatomy in the University of St. Andrews.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1906. ‡Myddelton-Gavey, E. H., J.P., F.R.G.S. Stanton Prior, Meads, Eastbourne.
1913. §Myddelton-Gavey, Miss Violet. Stanton Prior, Meads, Eastbourne.
1902. ‡Myddleton, Alfred. 62 Duncairn-street, Belfast.
1902. *Myers, Charles S., M.A., M.D. Great Shelford, Cambridge.
1909. *Myers, Henry. The Long House, Leatherhead.
1906. ‡Myers, Jesse A. Glengarth, Walker-road, Harrogate.

Year of Election.

1890. *Myres, John L., M.A., F.S.A. (Pres. H, 1909; Council, 1909–), Wykeham Professor of Ancient History in the University of Oxford. 101 Banbury-road, Oxford.
1914. *Myres, Miles Claude. 101 Banbury-road, Oxford.

1886. ‡Nagel, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1892. *Nairn, Sir Michael B., Bart. Kirkcaldy, N.B.
1890. ‡Nalder, Francis Henry. 34 Queen-street, E.C.
1908. ‡Nally, T. H. Temple Hill, Terenure, Co. Dublin.
1909. ‡Neild, Frederic, M.D. Mount Pleasant House, Tunbridge Wells.
1883. *Neild, Theodore, M.A. Grange Court, Leominster.
1914. §Nelson, Miss Edith A., M.A., M.Sc. 131 Williams-road, East Prahran, Victoria.
1914. *Nettlefold, J. S. Winterbourne, Edgbaston Park-road, Birmingham.
1914. §Nettlefold, Miss. Winterbourne, Edgbaston Park-road, Birmingham.
1898. *Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡Neville, F. H., M.A., F.R.S. Sidney College, Cambridge.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S., Professor of Astrophysics in the University of Cambridge. Madingley Rise, Cambridge.
1912. ‡Newberry, Percy E., M.A., Professor of Egyptology in the University of Liverpool. Oldbury Place, Ightham, Kent.
1901. ‡Newbigin, Miss Marion, D.Sc. Royal Scottish Geographical Society, Edinburgh.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1913. §Newman, L. F. 2 Warkworth-street, Cambridge.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.
1912. *Newton, Arthur U. University College, W.C.
1892. ‡Newton, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N.
1914. §Newton, R. Bullen, F.G.S. British Museum (Natural History), South Kensington, S.W.
1914. §Nicholls, Dr. E. Brooke. 174 Victoria-street, North Melbourne.
1908. ‡Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. ‡Nichols, Albert Russell. 30 Grosvenor-square, Rathmines, Co. Dublin.
1908. §Nicholson, J. W., M.A., D.Sc. Highcliffe, Redcar, Yorkshire.
1887. ‡Nicholson, John Carr, J.P. Moorfield House, Headingley, Leeds.
1884. ‡Nicholson, Joseph S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh.
1911. ‡Nicol, J. C., M.A. The Grammar School, Portsmouth.
1908. ‡Nixon, The Right Hon. Sir Christopher, Bart., M.D., LL.D., D.L. 2 Merrion-square, Dublin.
1863. *Noble, Sir Andrew, Bart., K.C.B., D.Sc., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890; Council, 1903–06; Local Sec. 1863.) Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1863. §Norman, Rev. Canon Alfred Merle, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1913. §Norman, Sir Henry, M.P. The Corner House, Cowley-street. S.W.
1912. ‡Norrie, Robert. University College, Dundee.

Year of Election.

1913. §Norris, F. Edward. Seismograph Station, Hill View, Woodbridge Hill, Guildford.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1909. ‡Nugent, F. S. 81 Notre Dame-avenue, Winnipeg, Canada.
1910. §Nunn, T. Percy, M.A., D.Sc., Professor of Education in the University of London. London Day Training College, Southampton-row, W.C.
1913. §Nuttall, T. E., M.D. Middleton, Huncoat, Accrington.
1912. ‡Nuttall, W. H. Cooper Laboratory for Economic Research, Rickmansworth-road, Watford.
1908. ‡Nutting, Sir John, Bart. St. Helen's, Co. Dublin.

1898. *O'Brien, Neville Forth. Fryth, Pyrford, Surrey.
1908. ‡O'Carroll, Joseph, M.D. 43 Merrion-square East, Dublin.
1913. §Ockenden, Maurice A., F.G.S. Oil Well Supply Company, Dashwood House, New Broad-street, E.C.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.
1910. *Odling, Marmaduke, B.A., F.G.S. Geological Department, The University, Leeds.
1858. *ODLING, WILLIAM, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council, 1865–70.) 15 Norham-gardens, Oxford.
1911. *O'DONOGHUE, CHARLES H., D.Sc. University College, Gower-street, W.C.
1908. §O'Farrell, Thomas A., J.P. 30 Lansdowne-road, Dublin
1902. ‡Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1913. §Ogilvie, A. G. 15 Evelyn-gardens, S.W.
1876. ‡Ogilvie, Campbell P. Lawford-place, Manningtree.
1914. §Ogilvie, Mrs. Campbell P. Lawford-place, Manningtree.
1885. ‡OGILVIE, F. GRANT, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W.
1912. §Ogilvy, J. W. 18 Bloomsbury-square, W.C.
1905. *Oke, Alfred William, B.A., LL.M., F.G.S., F.L.S. 32 Denmark-villas, Hove, Brighton.
1905. §Okell, Samuel, F.R.A.S. Overley, Langham-road, Bowdon, Cheshire.
1908. §Oldham, Charles Hubert, B.A., B.L., Professor of Commerce in the National University of Ireland. 5 Victoria-terrace, Rathgar, Dublin.
1892. ‡OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *OLDHAM, R. D., F.R.S., F.G.S. 8 North-street, Horsham, Sussex.
1912. §O'Leary, Rev. William, S.J. Mungret College, Limerick.
1914. §Oliver, Calder E. Manor-street, Brighton, Victoria.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906), Professor of Botany in University College, London, W.C.
1889. ‡Oliver, Professor Sir Thomas, M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §OLSEN, O. T., D.Sc., F.L.S., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael and All Angels, Portsea, Hants.
1908. ‡O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.

Year of Election.

1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.
1913. §Orange, J. A. General Electric Company, Schenectady, New York, U.S.A.
1905. ‡O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1884. *Orpen, Rev. T. H., M.A. Mark Ash, Abinger Common, Dorking.
1901. ‡Orr, Alexander Stewart. 10 Medows-street, Bombay, India.
1909. ‡Orr, John B. Crossacres, Woolton, Liverpool.
1908. *Orr, William. Dungarvan, Co. Waterford.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1910. *Osborn, T. G. B., M.Sc., Professor of Botany in the University of Adelaide, South Australia.
1901. §Osborne, Professor W. A., D.Sc. The University, Melbourne.
1908. ‡O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1887. ‡O'Shea, L. T., B.Sc. University College, Sheffield.
1884. ‡Osler, Sir William, Bart., M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. 13 Norham-gardens, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1911. §Owens, J. S., M.D., Assoc.M.Inst.C.E. 47 Victoria-street, S.W.
1910. *Oxley, A. E. Rose Hill View, Kimberworth-road, Rotherham.

1909 ‡Pace, F. W. 388 Wellington-crescent, Winnipeg, Canada.
1908. ‡Pack-Beresford, Denis, M.R.I.A. Fenagh House, Bagenalstown, Ireland.
1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1883. ‡Page, G. W. Bank House, Fakenham.
1913. §Paget, Sir Richard, Bart. Old Fallings Hall, Wolverhampton.
1911. §Paget, Stephen, M.A., F.R.C.S. 21 Ladbroke-square, W.
1912. ‡Pahic, Paul. 52 Albert Court, Kensington Gore, S.W.
1911. ‡Paine, H. Howard. 50 Stow-hill, Newport, Monmouthshire.
1870. *Palgrave, Sir Robert Harry Inglis, F.R.S., F.S.S. (Pres. F, 1883.) Henstead Hall, Wrentham, Suffolk.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1878. *Palmer, Joseph Edward. Royal Societies Club, St. James's-street, S.W.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1904. ‡Parker, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1909. §Parker, M. A., B.Sc., F.C.S. (Local Sec. 1909), Professor of Chemistry in the University of Manitoba, Winnipeg, Canada.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1905. **Parkes, Tom E. P.O. Box* 4580, *Johannesburg.*
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.L.S., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. Broomhill House, Watson-road, Sheffield.
1911. ‡Parks, Dr. G. J. 18 Cavendish-road, Southsea.
1913. §Parry, Edward, M.Inst.C.E. Rossmore, Leamington.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. ‡Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.

Year of Election.

1878. ‡PARSONS, Hon. Sir C. A., K.C.B., M.A., Sc.D., F.R.S., M.Inst.C.E. (Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. ‡Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Worting House, Basingstoke, Hants.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in the University of Liverpool.
1908. ‡Paterson, M., LL.D. 7 Halton-place, Edinburgh.
1909. ‡Paterson, William. Ottawa, Canada.
1897. ‡Paton, D. Noël, M.D., F.R.S., Professor of Physiology in the University of Glasgow.
1883. *Paton, Rev. Henry, M.A. Airtnoch, 184 Mayfield-road, Edinburgh.
1884. *Paton, Hugh. Box 2646, Montreal, Canada.
1913. §Patrick, Joseph A. North Cliff, King's Heath, Birmingham.
1908. §PATTEN, C. J., M.A., M.D., Sc.D., Professor of Anatomy in the University of Sheffield.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1913. ‡Patterson, W. Hamilton, M.Sc. The Monksferry Laboratory, Birkenhead.
1913. *Pattin, Harry Cooper, M.A., M.D. King-street House, Norwich.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 32 Harlow Moor-drive, Harrogate.
1887. *Paxman, James. Standard Iron Works, Colchester.
1912. *Payne, Miss Edith. Care of Mrs. Roberts, Lothair, St. Marychurch, Torquay.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1914. *Payne, Professor Henry, M.Inst.C.E. The University, Melbourne.
1888. *Paynter, J. B. Hendford Manor, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Manchester.
1906. ‡Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.
1885. ‡PEACH, B. N., LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1912.) Geological Survey Office, George-square, Edinburgh.
1911. §Peake, Harold J. E. Westbrook House, Newbury.
1913. ‡Pear, T. H. Dunwood House, Withington, Manchester.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1883. ‡Pearson, Arthur A., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. ‡Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1905. *PEARSON, Professor H. H. W., M.A., F.L.S. National Botanic Gardens, Kirstenbosch, Newlands, Cape Town.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.
1906. ‡Pearson, Dr. Joseph. The Museum, Colombo, Ceylon.
1904. ‡Pearson, Karl, M.A., F.R.S., Professor of Eugenics in the University of London. 7 Well-road, Hampstead, N.W.
1909. ‡Pearson, William. Wellington-crescent, Winnipeg, Canada.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *PECKOVER, Lord, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, Ph.D., F.R.S.E., Professor of Natural Philosophy in University College, Dundee.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.

Year of Election.

1878. *Peek, William. Villa des Jonquilles, Rue des Roses, Monte Carlo.
1901. *Peel, Right Hon. Viscount. 13 King's Bench-walk, Temple, E.C.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1905. ‡Pemberton, Gustavus M. P.O. Box 93, Johannesburg.
1887. ‡PENDLEBURY, WILLIAM H., M.A., F.C.S. (Local Sec. 1899.) Woodford House, Mountfields, Shrewsbury.
1894. ‡Pengelly, Miss. Lamorna, Torquay.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 1 Chesham-street, S.W.
1908. ‡Percival, Professor John, M.A. University College, Reading.
1905. ‡Péringuey, L., D.Sc., F.Z.S. South African Museum, Cape Town.
1894. ‡PERKIN, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1902. *Perkin, F. Mollwo, Ph.D. 199 Piccadilly, W.
1884. ‡PERKIN, WILLIAM HENRY, LL.D. Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901–07), Waynflete Professor of Chemistry in the University of Oxford. The Museums, Oxford.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1909. ‡Perry, Rev. Professor E. Guthrie. 246 Kennedy-street, Winnipeg, Canada.
1874. *PERRY, Professor JOHN, M.E., D.Sc., LL.D., F.R.S. (GENERAL TREASURER, 1904– ; Pres. G, 1902; Pres. L, 1914; Council, 1901–04). 25 Stanley-crescent, W.
1913. ‡Perry, W. J. Care of W. J. Roberts, The Mount, Church Stretton.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. *PETAVEL, J. E., M.Sc., F.R.S., Professor of Engineering in the University of Manchester.
1914. *Peters, Thomas. Burrinjuck viâ Goondah, N.S.W.
1901. ‡Pethybridge, G. H., Ph.D. Royal College of Science, Dublin.
1910. *Petrescu, Captain Dimitrie, R.A., M.Eng. Scoala Superiora de Messern, Bucharest, Rumania.
1895. ‡PETRIE, W. M. FLINDERS, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. Vale House, St. Helier, Jersey.
1886. ‡Phelps, Lieut.-General A. 23 Augustus-road, Edgbaston, Birmingham.
1911. ‡Philip, Alexander. Union Bank Buildings, Brechin.
1903. ‡*Philip, James C. 20 Westfield-terrace, Aberdeen.*
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1863. ‡Philipson, Sir G. H., D.C.L. 7 Eldon-square, Newcastle-on-Tyne.
1905. ‡Phillimore, Miss C. M. Shiplake House, Henley-on-Thames.
1899. *Phillips, Charles E. S., F.R.S.E. Castle House, Shooter's Hill, Kent.
1910. *Phillips, P. P., Ph.D., Professor of Chemistry in the Thomason Engineering College, Rurki, United Provinces, India.
1890. ‡PHILLIPS, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1909. *Phillips, Richard. 15 Dogpole, Shrewsbury.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Billinge View, Blackburn.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1907. ‡Pickles, A. R., M.A. Todmorden-road, Burnley.

Year of Election

1888. *Pidgeon, W. R. Lynsted Lodge, St. Edmund's-terrace, Regent's Park, N.W.
1865. ‡PIKE, L. OWEN. 10 Chester-terrace, Regent's Park, N.W.
1896. *Pilkington, A. C. Rocklands, Rainhill, Lancashire.
1905. ‡Pilling, Arnold. Royal Observatory, Cape Town.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1905. ‡Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1911. ‡Pink, H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. J. E. The Homestead, Eastern-parade, Southsea.
1908. *Pio, Professor D. A. 14 Leverton-street, Kentish Town, N.W.
1908. ‡Pirrie, The Right Hon. Lord, LL.D., M.Inst.C.E. Downshire House, Belgrave-square, S.W.
1909. ‡Pitblado, Isaac, K.C. 91 Balmoral-place, Winnipeg, Canada.
1893. *PITT, WALTER, M.Inst.C.E. 3 Lansdown-grove, Bath.
1900. *Platts, Walter. Morningside, Scarborough.
1911. *Plimmer, R. H. A. 3 Hall-road, N.W.
1898. ‡Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1908. ‡Plunkett, Count G. N. National Museum of Science and Art, Dublin.
1908. ‡Plunkett, Colonel G. T., C.B. Belvedere Lodge, Wimbledon, S.W.
1907. *PLUNKETT, Right Hon. Sir HORACE, K.C.V.O., M.A., F.R.S. Kilteragh, Foxrock, Co. Dublin.
1900. *Pocklington, H. Cabourn, M.A., D.Sc., F.R.S. 5 Wellclose-place, Leeds.
1913. ‡Pocock, R. J. St. Aidan's, 170 Eglinton-road, Woolwich, S.E.
1914. §Pollock, Professor J. A., D.Sc The University, Sydney, N.S.W.
1908. ‡Pollok, James H., D.Sc. 6 St. James's-terrace, Clonshea, Dublin.
1906. *Pontifex, Miss Catherine E. 7 Hurlingham-court, Fulham, S.W.
1891. ‡Pontypridd, Lord. Pen-y-lan, Cardiff.
1911. ‡Poore, Major-General F. H. 1 St. Helen's-parade, Southsea.
1907. §Pope, Alfred, F.S.A. South Court, Dorchester.
1900. *POPE, W. J., M.A., LL.D., F.R.S. (Pres. B, 1914), Professor of Chemistry in the University of Cambridge. Chemical Laboratory, The University, Cambridge.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Bowden-lane, Marple, Cheshire.
1901. §PORTER, ALFRED W., B.Sc., F.R.S. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1905. §PORTER, J. B., D.Sc., M.Inst.C.E., Professor of Mining in the McGill University, Montreal, Canada.
1905. ‡Porter, Mrs. McGill University, Montreal, Canada.
1883. ‡POTTER, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1907. ‡Potts, F. A. University Museum of Zoology, Cambridge.
1908. *Potts, George, Ph.D., M.Sc. Grey University College, Bloemfontein, South Africa.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895–1901, 1905–12), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham House, Banbury-road, Oxford.

Year of Election.

1913. §Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1913. ‡Poynting, Mrs. J. H. 10 Ampton-road, Edgbaston, Birmingham.
1908. ‡Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *Prain, Lieut.-Col. Sir David, C.I.E., C.M.G., M.B., F.R.S. (Pres. K, 1909; Council, 1907-14.) Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1913. *Prankerd, Mrs. Theodora Lisle. 25 Hornsey Lane-gardens, N.
1888. *Preece, W. Llewellyn, M.Inst.C.E. 8 Queen Anne's-gate, S.W.
1904. §Prentice, Mrs. Manning. Thelema, Undercliff-road, Felixstowe.
1892. ‡Prentice, Thomas. Willow Park, Greenock.
1906. ‡Pressly, D. L. Coney-street, York.
1889. ‡Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1914. §Preston, C. Payne. Australian Distillery Co., Byrne-street, South Melbourne.
1914. §Preston, Miss E. W. 153 Barry-street, Carlton, Victoria.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
1888 ‡Price, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898-1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1913. §Price, T. Slater. Municipal Technical School, Suffolk-street, Birmingham.
1897. *Price, W. A., M.A. 135 Sandyford-road, Newcastle-on-Tyne.
1914. §Priestley, Professor H. J. Edale, River-terrace, Kangaroo Point, Brisbane, Australia.
1908. §Priestley, J. H., B.Sc., Professor of Botany in the University of Leeds.
1909. *Prince, Professor E. E., LL.D., Dominion Commissioner of Fisheries. 206 O'Connor-street, Ottawa, Canada.
1914. §Pringsheim, Dr. Peter. Lutzemstrasse 63, Berlin.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *Pritchard, Urban, M.D., F.R.C.S. 26 Wimpole-street, W.
1881. §Procter, John William. Ashcroft, York.
1884. *Proudfoot, Alexander, M.D. Care of E. C. S. Scholefield, Esq., Provincial Librarian, Victoria, B.C., Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1913. §Pullar, W. B. Coniston, Bridge of Allan, N.B.
1903. ‡Pullen-Burry, Miss. Lyceum Club, 128 Piccadilly, W.
1904. ‡Punnett, R. C., M.A., F.R.S., Professor of Biology in the University of Cambridge. Caius College, Cambridge.
1885. ‡Purdie, Thomas, B.Sc., Ph.D., F.R.S., Emeritus Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1913. ‡Purser, G. Leslie. Gwynfa, Selly Oak, Birmingham.
1913. ‡Purser, John, M.Sc. The University, Edgbaston, Birmingham.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1911. ‡Purvis, J. E. Corpus Christi College, Oxford.
1912. ‡Pycraft, Dr. W. P. British Museum (Natural History), Cromwell-road, S.W.

Year of Election

1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. 32 Queen Victoria-street, E.C.
1883. ‡Pye-Smith, Mrs. 32 Queen Victoria-street, E.C.
1879. ‡Pye-Smith, R. J. 450 Glossop-road, Sheffield.
1911. ‡Pye-Smith, Mrs. R. J. 450 Glossop-road, Sheffield.

1893. ‡Quick, James. 22 Bouverie-road West, Folkestone.
1906. *Quiggin, Mrs. A. Hingston. 88 Hartington-grove, Cambridge.

1879. ‡Radford, R. Heber. 15 St. James's-row, Sheffield.
1912. ‡*Radok, F. 12 Central-hill, Upper Norwood, S.E.*
1911. §Rae, John T. National Temperance League, Paternoster House, Paternoster-row, E.C.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1913. ‡Railing, Dr. A. H., B.Sc. The General Electric Co., Ltd., Witton, Birmingham.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *Ramage, Hugh, M.A. The Technical Institute, Norwich.
1894. *Rambaut, Arthur A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1908. ‡Rambaut, Mrs. Radcliffe Observatory, Oxford.
1912. ‡Ramsay, Colonel R. G. Wardlaw. Whitehill, Rosewell, Midlothian.
1876. *Ramsay, Sir William, K.C.B., Ph.D., D.Sc., F.R.S. (President, 1911; Pres. B. 1897; Council 1891–98) Beechcroft, Hazlemere, High Wycombe.
1883. ‡Ramsay, Lady. Beechcroft, Hazlemere, High Wycombe
1914. §Ramsbottom, J. W. 23 Rosebery-crescent, Newcastle-on-Tyne.
1913. §Ramsden, William. Blacker-road, Huddersfield.
1907. ‡Rankine, A. O., D.Sc. 18 Loveday-road, Ealing, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Dean Park, Bournemouth.
1903. ‡Rastall, R. H. Christ's College, Cambridge.
1914. §Rathbone, Herbert R. 15 Lord-street, Liverpool.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1913. ‡Raw, Frank, B.Sc., F.G.S. The University, Edmund-street, Birmingham.
1914. §Rawes-Whittell, H. Manchester Hall, 183 Elizabeth-street, Sydney, N.S.W.
1908. *Raworth, Alexander. St. John's Manor, Jersey.
1905. ‡Rawson, Colonel Herbert E., C.B., R.E., F.R.G.S. Home Close, Heronsgate, Herts.
1868. *Rayleigh, The Right Hon. Lord, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. (President, 1884; Trustee, 1883– ; Pres. A, 1882; Council, 1878–83), Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1912. §Rayner, Miss M. C., D.Sc. University College, Reading.
1897. *Rayner, Edwin Hartree, M.A. 40 Gloucester-road, Teddington, Middlesex.
1907. ‡Rea, Carleton, B.C.L. 34 Foregate-street, Worcester.
1913. §Read, Carveth, M.A. 73 Kensington Gardens-square, W.

Year of
Election.

1896. *READ, Sir CHARLES H., LL.D., F.S.A. (Pres. H, 1899.) British Museum, W.C.
1913. §Reade, Charles C. 3 Gray's Inn-place, Gray's Inn, W.C.
1914. §Reade, Mrs. C. C. 3 Gray's Inn-place, Gray's Inn, W.C.
1902. ‡Reade, R. H. Wilmount, Dunmurry.
1884. §Readman, J. B., D.Sc., F.R.S.E. Belmont, Hereford.
1890. *Redwood, Sir Boverton, Bart., D.Sc., F.R.S.E., F.C.S. The Cloisters, 18 Avenue-road, Regent's Park, N.W.
1908. ‡Reed, Sir Andrew, K.C.B., C.V.O., LL.D. 23 Fitzwilliam-square, Dublin.
1905. ‡Reed, J. Howard, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunscar, Oaken, near Wolverhampton.
1903. ‡Reeves, E. A., F.R.G.S. Hillside, Reigate-road, Reigate.
1911. §REEVES, Hon. W. PEMBER. (Pres. F, 1911.) London School of Economics, Clare Market, W.C.
1906. *Reichel, Sir Harry R., M.A., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1910. *Reid, Alfred, M.B., M.R.C.S. Kuala, Lumpur, Selangor, F.M.S.
1901. *Reid, Andrew T. 10 Woodside-terrace, Glasgow.
1904. ‡Reid, Arthur H. 30 Welbeck-street, W.
1881. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. One Acre, Milford-on-Sea, Hants.
1903. *Reid, Mrs. E. M., B.Sc. One Acre, Milford-on-Sea, Hants.
1892. ‡REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1908. ‡REID, GEORGE ARCHDALL, M.B., C.M., F.R.S.E. 9 Victoria-road South, Southsea.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1909. ‡Reid, John Young. 329 Wellington-crescent, Winnipeg, Canada.
1904. ‡Reid, P. J. Marton Moor End, Nunthorpe, R.S.O., Yorkshire.
1912. §Reid, Professor R. W., M.D. 37 Albyn-place, Aberdeen.
1897. ‡Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. Municipal Technical School, Birmingham.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1912. §Reinheimer, Hermann. 43 King Charles-road, Surbiton.
1875. ‡REINOLD, A. W., C.B., M.A., F.R.S. (Council, 1890–95.) 3 Lennox-mansions, Southsea.
1894. ‡Rendall, Rev. G. H., M.A., Litt.D. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. *RENDLE, Dr. A. B., M.A., F.R.S., F.L.S. 28 Holmbush-road, Putney, S.W.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1906. ‡Rennie, John, D.Sc. Natural History Department, University of Aberdeen.
1905. *Renton, James Hall. Rowfold Grange, Billingshurst, Sussex.
1912. ‡Rettie, Theodore. 10 Doune-terrace, Edinburgh.
1904. ‡REUNERT, THEODORE, M.Inst.C.E. P.O. Box 92, Johannesburg.
1912. ‡Rew, R. H., C.B. Board of Agriculture and Fisheries, 3 St. James's-square, S.W.
1905. §Reyersbach, Louis. Care of Messrs. Wernher, Beit, & Co., 1 London Wall-buildings, E.C.
1883. *Reynolds, A. H. 271 Lord-street, Southport.
1913. ‡Reynolds, J. H. Low Wood, Harborne, Birmingham.

Year of Election.

1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A. (Pres. B, 1893; Council, 1893-99.) 3 Inverness-gardens, W.
1900. *Reynolds, Miss K. M. 8 Darnley-road, Notting Hill, W.
1906. ‡Reynolds, S. H., M.A., Sc.D., Professor of Geology in the University of Bristol.
1907. §Reynolds, W. Birstall Holt, near Leicester.
1899. *RHYS, The Right Hon. Professor Sir JOHN, D.Sc. (Pres. H, 1900.) Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro 14, Modena, Italy.
1905. §Rich, Miss Florence, M.A. Granville School, Granville-road, Leicester.
1906. ‡Richards, Rev. A. W. 12 Bootham-terrace, York.
1914. §Richardson, A. E. V., M.A., B.Sc. Department of Agriculture, Melbourne.
1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
1912. ‡Richardson, Harry, M.Inst.E.E. Electricity Supply Department, Dudhope Crescent-road, Dundee.
1889. ‡Richardson, Hugh, M.A. 18 Bootham-crescent, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans, M.A., D.Sc., F.R.S., Wheatstone Professor of Physics in King's College, London, W.C.
1914. *Rideal, Eric K., B.A., Ph.D. 28 Victoria-street, S.W.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1911. ‡Ridgeway, Miss A. R. 83 The Broadway, Watford.
1902. §RIDGEWAY, WILLIAM, M.A., D.Litt., F.B.A. (Pres. H, 1908), Professor of Archæology in the University of Cambridge. Flendyshe, Fen Ditton, Cambridge.
1913. §Ridler, Miss C. C. Coniston, Hunsdon-road, Torquay.
1894. ‡RIDLEY, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1881. *Rigg, Arthur. 150 Blomfield-terrace, W.
1883. *RIGG, EDWARD, C.B., I.S.O., M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1912. §Rintoul, Miss L. J. Lahill, Largo, Fife.
1910. ‡Ripper, William, Professor of Engineering in the University of Sheffield.
1903. *RIVERS, W. H. R., M.D., F.R.S. (Pres. H, 1911.) St. John's College, Cambridge.
1913. §RIVETT, A. C. D., B.A., Ph.D. (General Organising Secretary, 1914.) The University of Melbourne, Victoria.
1908. *Roaf, Herbert E., M.D., D.Sc. 44 Rotherwick-road, Hendon, N.W.
1898. *Robb, Alfred A., M.A., Ph.D. Lisnabreeny House, Belfast.
1914. §Robb, James Jenkins, M.D. Harlow, 19 Linden-road, Bournville, Birmingham.
1902. *Roberts, Bruno. 30 St. George's-square, Regent's Park, N.W.
1887. *Roberts, Evan. 27 Crescent-grove, Clapham Common, S.W.
1896. ‡Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1913. §Robertson, Andrew. Engineering Laboratories, Victoria University, Manchester.
1897. §ROBERTSON, Sir GEORGE S., K.C.S.I., M.P. (Pres. E, 1900.) 2 Mitre Court-buildings, Temple, E.C.
1897. ‡Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue, Quebec, Canada.

Year of Election.

1912. §Robertson, R. A., M.A., B.Sc., F.R.S.E., Lecturer on Botany in the University of St. Andrews.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. Carnbooth, Carmunnock, Lanarkshire.
1913. *Robins, Edward, M.Inst.C.E., F.R.G.S. Lobito, Angola, Portuguese South-West Africa.
1913. ‡Robinson, A. H., M.D. St. Mary's Infirmary, Highgate Hill, N.
1886. *Robinson, Charles Reece. 176 Gerrard-street, Aston, Birmingham.
1909. ‡Robinson, E. M. 381 Main-street, Winnipeg, Canada.
1903. ‡Robinson, G. H. 1 Weld-road, Southport.
1902. ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1911. ‡Robinson, J. J. 'West Sussex Gazette' Office, Arundel.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.
1912. §Robinson, James. 42 Fordbrook-avenue, Ealing Common, W.
1888. ‡Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1908. *Robinson, John Gorges, B.A. Cragdale, Settle, Yorkshire.
1910. ‡Robinson, John Hargreaves. Cable Ship 'Norseman,' Western Telegraph Co., Caixa no Correu No. 117, Pernambuco, Brazil.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1899. *Robinson, Mark, M.Inst.C.E. Parliament-chambers, Westminster, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1908. ‡Robinson, Robert. Field House, Chesterfield.
1904. ‡Robinson, Theodore R. 25 Campden Hill-gardens, W.
1909. ‡Robinson, Captain W. 264 Roslyn-road, Winnipeg, Canada.
1909. ‡Robinson, Mrs. W. 264 Roslyn-road, Winnipeg, Canada.
1904. ‡Robinson, W. H. Kendrick House, Victoria-road, Penarth.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1912. ‡Robson, W. G. 50 Farrington-street, Dundee.
1896. ‡Rodger, A. M. Natural History Museum, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1905. ‡Roebuck, William Denison, F.L.S. 259 Hyde Park-road, Leeds.
1908. ‡Rogers, A. G. L. Board of Agriculture and Fisheries, 8 Whitehall-place, S.W.
1898. ‡ROGERS, BERTRAM, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
1913. ‡Rogers, F., D.Eng., B.A., M.Sc. Rowardennan, Chelsea-road, Sheffield.
1913. ‡Rogers, Sir Hallewell. Greville Lodge, Sir Harry's-road, Edgbaston, Birmingham.
1907. ‡Rogers, John D. 85 St. George's-square, S.W.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 6 Hollin-lane, Leeds.
1906. ‡Rogers, Reginald A. P. Trinity College, Dublin.
1909. ‡Rogers, Hon. Robert. Roslyn-road, Winnipeg, Canada.
1884. *Rogers, Walter. Lamorva, Falmouth.
1876. ‡ROLLIT, Sir A. K., LL.D., D.C.L., Litt.D. St. Anne's Hall, near Chertsey-on-Thames, Surrey.
1855. *ROSCOE, The Right Hon. Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. (PRESIDENT, 1887; Pres. B, 1870, 1884; Council, 1874–81; Local Sec. 1861.) 10 Bramham-gardens, S.W.
1905. ‡Rose, Miss G. Mabel. Ashley Lodge, Oxford.
1883. *Rose, J. Holland, Litt.D. Walsingham, Millington-road, Cambridge.
1894. *ROSE, Sir T. K., D.Sc., Chemist and Assayer to the Royal Mint. 6 Royal Mint, E.

Year of Election.

1905. *Rosedale, Rev. H. G., D.D., F.S.A. 7 Gloucester-street, S.W.
1905. *Rosedale, Rev. W. E., D.D. St. Mary Bolton's Vicarage, South Kensington, S.W.
1900. ‡ROSENHAIN, WALTER, B.A., F.R.S. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. §Rosenhain, Mrs. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. §Rosenhain, Miss. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. §Ross, Alexander David, M.A., D.Sc., F.R.A.S., F.R.S.E., Professor of Mathematics and Physics in the University of Western Australia, Perth, Western Australia.
1909. ‡Ross, D. A. 116 Wellington-crescent, Winnipeg, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1908. ‡Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
1912. ‡Ross, Miss Joan M. Hazelwood, Warlingham, Surrey.
1902. ‡Ross, John Callender. 46 Holland-street, Campden-hill, W.
1901. ‡Ross, Colonel Sir RONALD, K.C.B., F.R.S., Professor of Tropical Sanitation in the University of Liverpool. The University, Liverpool.
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
1911. *Rothschild, Hon. L. Walter, M.P., D.Sc., Ph.D., F.R.S. Tring Park, Tring.
1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1884. *Rouse, M. L., B.A. 47 Berlin-road, Catford, S.E.
1905. §Rousselet, Charles F. Fir Island, Bittacy Hill, Mill Hill, N.W.
1901. ‡Rowallan, the Right Hon. Lord. Thornliebank House, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. Shottendane, Margate.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood Leeds.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1910. ‡Rowse, Arthur A., B.A., B.Sc. *Engineering Laboratory, Cambridge.*
1875. *RÜCKER, Sir ARTHUR W., M.A., D.Sc., LL.D., F.R.S. (PRESIDENT, 1901; TRUSTEE, 1898- ; GENERAL TREASURER, 1891–98; Pres. A, 1894; Council, 1888–91.) Everington House, Newbury, Berkshire.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. 52 Cranley-gardens, Muswell Hill, N.
1905. *Ruffer, Marc Armand, C.M.G., M.A., M.D., B.Sc. Quarantine International Board, Alexandria.
1905. ‡Ruffer, Mrs. Alexandria.
1904. ‡Ruhemann, Dr. S., F.R.S. 3 Selwyn-gardens, Cambridge.
1909. ‡Rumball, Rev. M. C., B.A. Morden, Manitoba, Canada.
1896. *Rundell, T. W., F.R.Met.Soc. Terras Hill, Lostwithiel.
1911. ‡Rundle, Henry, F.R.C.S. 13 Clarence-parade, Southsea.
1912. *Rusk, Robert R., M.A., Ph.D. 4 Barns-crescent, Ayr.
1904. ‡Russell, E. J., D.Sc. Rothamsted Experimental Station, Harpenden, Herts.
Russell, John. 39 Mountjoy-square, Dublin.
1883. *Russell, J. W. 28 Staverton-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W.
1908. ‡Russell, Robert. Arduagremia, Haddon-road, Dublin.
1908. ‡RUSSELL, Right Hon. T. W., M.P. Olney, Terenure, Co. Dublin.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1909. *Rutherford, Hon. Alexander Cameron. Strathcona, Alberta, Canada.
1907. §RUTHERFORD, Sir ERNEST, M.A., D.Sc., F.R.S. (Pres. A, 1909; Council, 1914–), Professor of Physics in the University of Manchester.

Year of Election.

1914. §Rutherford, Lady. 17 Wilmslow-road, Withington, Manchester.
1914. §Rutherford, Miss Eileen. 17 Wilbraham-road, Withington, Manchester.
1909. ‡Ruttan, Colonel H. N. Armstrong's Point, Winnipeg, Canada.
1908. ‡Ryan, Hugh, D.Sc. Omdurman, Orwell Park, Rathgar, Dublin.
1905. ‡Ryan, Pierce. Rosebank House, Rosebank, Cape Town.
1909. ‡Ryan, Thomas. Assiniboine-avenue, Winnipeg, Canada.
1906. *Rymer, Sir Joseph Sykes. The Mount, York.

1903. ‡Sadler, M. E., C.B., LL.D. (Pres. L, 1906), Vice-Chancellor of the University of Leeds. 41 Headingley-lane, Leeds.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Church House, Westminster, S.W.
1903. ‡Sagar, J. The Poplars, Savile Park, Halifax.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1904. ‡Salter, A. E., D.Sc., F.G.S. 5 Clifton-place, Brighton.
1911. §Sampson, R. A., M.A., F.R.S., Astronomer Royal for Scotland. Royal Observatory, Edinburgh.
1901. ‡Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1907. *Sand, Dr. Henry J. S. University College, Nottingham.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, M.Inst.C.E. Toolerstone, Sandiway, Cheshire.
1896. ‡Saner, Mrs. Toolerstone, Sandiway, Cheshire.
1903. ‡Sankey, Captain H. R., R.E., M.Inst.C.E. Palace-chambers, 9 Bridge-street, S.W.
1886. ‡Sankey, Percy E. 44 Russell-square, W.C
1905. ‡*Sargant, E. B. Quarry Hill, Reigate.*
1896. *Sargant, Miss Ethel, F.L.S. (Pres. K, 1913.) The Old Rectory, Girton, Cambs.
1907. ‡Sargent, H. C. Ambergate, near Derby.
1913. ‡Saundby, Robert, M.D. Great Charles-street, Birmingham.
1903. *Saunders, Miss E. R. (Council, 1914- .) Newnham College, Cambridge.
1887. §Sayce, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1906. ‡Sayer, Dr. Ettie. 35 Upper Brook-street, W.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1903. ‡Scarisbrick, Sir Charles, J.P. Scarisbrick Lodge, Southport.
1903. ‡Scarisbrick, Lady. Scarisbrick Lodge, Southport.
1879. *Schäfer, Sir E. A., LL.D., D.Sc., M.D., F.R.S. (President, 1912; General Secretary, 1895-1900; Pres. I, 1894; Council, 1887-93), Professor of Physiology in the University of Edinburgh. Marly Knowe, North Berwick.
1914. §Schäfer, Lady. Marly Knowe, North Berwick.
1914. §Scharff, J. W. Knockranny, Bray, Co. Wicklow.
1888. *Scharff, Robert F., Ph.D., B.Sc., Keeper of the Natural History Department, National Museum, Dublin. Knockranny, Bray, Co. Wicklow.
1914. §Scharff, Mrs. Knockranny, Bray, Co. Wicklow.
1880. *Schemmann, Louis Carl. Neueberg 12, Hamburg.
1905. ‡Schönland, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.
1908. §Schrödter, Dr. E. 27 Breite-strasse, Düsseldorf, Germany.
1873. *Schuster, Arthur, Ph.D., Sec. R.S., F.R.A.S. (President Elect; Pres. A, 1892; Council, 1887-93.) Yeldall, Twyford, Berks.
1883. *Sclater, W. Lutley, M.A., F.Z.S. Odiham Priory, Winchfield.

Year of Election.

1905. ‡Sclater, Mrs. W. L. Odiham Priory, Winchfield.
1913. §Scoble, Walter A., B.Sc., A.M.Inst.C.E. City and Guilds Technical College, Leonard-street, E.C.
1881. *Scott, Alexander, M.A., D.Sc., F.R.S., F.C.S. 34 Upper Hamilton-terrace, N.W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1889. *Scott, D. H., M.A., Ph.D., F.R.S., Pres.L.S. (General Secretary, 1900–03; Pres. K, 1896.) East Oakley House, Oakley, Hants; and Athenæum Club, Pall Mall, S.W.
1857. *Scott, Robert H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1902. ‡Scott, William R., M.A., Litt.D. St. Regulus, St. Andrews, Scotland.
1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1909. ‡*Scudamore, Colonel F. W. Chelsworth Hall, Suffolk.*
1895. ‡Scull, Miss E. M. L. St. Edmund's, 10 Worsley-road, Hampstead, N.W.
1890. *Searle, G. F. C., Sc.D., F.R.S. Wyncote, Hills-road, Cambridge.
1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. Naval Observatory, Mare Island, California.
1907. §Seligman, Dr. C. G. 36 Finchley-road, N.W.
1911. *Seligman, Mrs. C. G. 36 Finchley-road, N.W.
1913. §Seligmann, Miss Emma A. 61 Kirklee-road, Kelvinside, Glasgow.
1904. ‡Sell, W. J. 19 Lensfield-road, Cambridge.
1909. ‡Sellars, H. Lee. 225 Fifth-avenue, New York, U.S.A.
1888. *Senier, Alfred, M.D., Ph.D., F.C.S. (Pres. B, 1912), Professor of Chemistry in University College, Galway.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1910. ‡Seton, R. S., B.Sc. The University, Leeds.
1895. *Seton-Karr, H. W. 8 St. Paul's-mansions, Hammersmith, W.
1892. *Seward, A. C., M.A., D.Sc., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901–07; Local Sec. 1904), Professor of Botany in the University of Cambridge. Westfield, Huntingdon-road, Cambridge.
1913. §Seward, Mrs. Westfield, Huntingdon-road, Cambridge.
1914. §Seward, Miss Phyllis. Westfield, Huntingdon-road, Cambridge.
1899. §Seymour, Henry J., B.A., F.G.S., Professor of Geology in the National University of Ireland. Earlsfort-terrace, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C. Burnt Green, Worcestershire.
1904. ‡Shackleton, Lieutenant Sir Ernest H., M.V.O., F.R.G.S. 9 Regent-street, S.W.
1902. ‡Shaftesbury, The Right Hon. the Earl of, K.P., K.C.V.O. Belfast Castle, Belfast.
1913. ‡Shakespear, G. A., D.Sc., M.A. 21 Woodland-road, Northfield, Worcestershire.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
1906. ‡Shann, Frederick. 6 St. Leonard's, York.
1878. ‡Sharp, David, M.A., M.B., F.R.S., F.L.S. Lawnside, Brockenhurst, Hants.
1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1914. §Shaw, A. G. Merton-crescent, Albert Park, Victoria.
1910. §Shaw, J. J. Sunnyside, Birmingham-road, West Bromwich.

Year of Election.

1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *SHAW, W. N., M.A., Sc.D., F.R.S. (Pres. A, 1908; Council, 1895–1900, 1904–07.) Meteorological Office, Exhibition-road, South Kensington, S.W.
1883. ‡Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
1903. ‡Shaw-Phillips, T., J.P. The Times Library Club, 380 Oxford-street, W.
1912. ‡Shearer, C. Clare College, Cambridge.
1905. ‡Shenstone, Miss A. Sutton Hall, Barcombe, Lewes
1905. ‡Shenstone, Mrs. A. E. G. Sutton Hall, Barcombe, Lewes.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1900. §SHEPPARD, THOMAS, F.G.S. The Municipal Museum, Hull.
1908. §Sheppard, W. F., Sc.D., LL.M. Board of Education, Whitehall, S.W.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1896. ‡SHERRINGTON, C. S., M.D., D.Sc., F.R.S. (Pres. I, 1904; Council, 1907–14), Professor of Physiology in the University of Oxford. 9 Chadlington-road, Oxford.
1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath.
1908. *Shickle, Miss Mabel G. M. 9 Cavendish-crescent, Bath.
1883. *Shillitoe, Buxton, F.R.C.S. Ardvernis, 3 Richmond-gardens, Bournemouth.
1887. *SHIPLEY, ARTHUR E., M.A., D.Sc., F.R.S. (Pres. D, 1909; Council, 1904–11), Master of Christ's College, Cambridge.
1897. ‡SHORE, Dr. LEWIS E. St. John's College, Cambridge.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. 6 Kingswood-road, Upper Norwood, S.E.
1901. ‡Short, Peter M., B.Sc. 1 Deronda-road, Herne Hill, S.E.
1908. §Shorter, Lewis R., B.Sc. 29 Albion-street, W.
1904. *Shrubsall, F. C., M.A., M.D. 34 Lime-grove, Uxbridge-road, W.
1910. ‡Shuttleworth, T. E. 5 Park-avenue, Riverdale-road, Sheffield.
1889. ‡Sibley, Walter K., M.A., M.D. 6 Cavendish-place, W.
1902. ‡Siddons, A. W., M.A. Harrow-on-the-Hill, Middlesex.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
1914. *Sidgwick, Mrs. E. M. 27 Grange-road, Cambridge.
1913. *SIDGWICK, N. V. Lincoln College, Oxford.
1873. *SIEMENS, ALEXANDER, M.Inst.C.E. Caxton House, Westminster, S.W.
1905. ‡Siemens, Mrs. A. Caxton House, Westminster, S.W.
1914. §Silberberg, H. B. 8 O'Connell-street, Sydney, N.S.W.
1903. *Silberrad, Dr. Oswald. Buckhurst Hill, Essex.
1915. §SIMON, Councillor E. D. (LOCAL SECRETARY, 1915.) 20 Mount-street, Manchester.
1871. *SIMPSON, Sir ALEXANDER R., M.D., Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh
1914. §Simpson, Dr. G. C. Meteorological Department, Simla, India.
1913. *Simpson, J. A., M.A., D.Sc. 62 Academy-street, Elgin.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1909. ‡Simpson, Professor J. C. McGill University, Montreal, Canada.
1908. ‡Simpson, J. J., M.A., B.Sc. Zoological Department, Marischal College, Aberdeen.
1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 25 Chester-street, Edinburgh.

Year of
Election.

1907. ‡Simpson, Lieut.-Colonel R. J. S., C.M.G. 66 Shooter's Hill-road, Blackheath, S.E.
1909. *Simpson, Samuel. B.Sc., Director of Agriculture, Kampala, Uganda.
1909. ‡Simpson, Sutherland, M.D. Cornell University Medical College. Ithaca, New York, U.S.A.
1896. *SIMPSON, W., F.G.S. Catteral Hall, Settle, Yorkshire.
1884. *Simpson, Professor W. J. R., C.M.G., M.D. 31 York-terrace, Regent's Park, N.W.
1909. ‡Sinclair, J. D. 77 Spence-street, Winnipeg.
1912. §Sinclair, Sir John R. G., Bart., D.S.O. Barrock House, Wick, N.B.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *SJÖGREN, Professor H. Natural History Museum, Stockholm, Sweden.
1914. §Skeats, Professor E. W., D.Sc. The University, Melbourne.
1902. ‡Skeffington, J. B., M.A., LL.D. Waterford.
1906. ‡Skerry, H. A. St. Paul's-square, York.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1910. ‡Skinner, J. C. 76 Ivy Park-road, Sheffield.
1898. ‡SKINNER, SIDNEY, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. *Skyrme, C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. §Skyrme, Mrs. C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. *SLADE, R. E., D.Sc. University College, Gower-street, W.C.
1887. ‡Small, Evan W., M.A., B.Sc., F.G.S. 48 Kedleston-road, Derby.
1903. *Smallman, Raleigh S. Eliot Lodge, Albemarle-road, Beckenham.
1902. ‡Smedley, Miss Ida. 36 Russell-square, W.C.
1911. ‡Smiles, Samuel. The Quarry, Sanderstead-road, Sanderstead, Surrey.
1911. §Smith, A. Malins, M.A. St. Audrey's Mill House, Thetford, Norfolk.
1914. §Smith, Professor A. Micah. School of Mines, Ballarat, Victoria.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Department of Chemistry, Columbia University, New York, U.S.A.
1908 ‡Smith, Alfred. 30 Merrion-square, Dublin.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *SMITH, Miss ANNIE LORRAIN. 20 Talgarth-road, West Kensington, W.
1914. §Smith, Arthur Elliot. 4 Willow Bank, Fallowfield, Manchester.
1873. ‡Smith, C. Sidney-Sussex College, Cambridge.
1889. *SMITH, Professor C. MICHIE, C.I.E., B.Sc., F.R.S.E., F.R.A.S. Winsford, Kodaikanal, South India.
1910. ‡Smith, Charles. 11 Winter-street, Sheffield.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1913. *Smith, Miss E. M. 40 Owlstone-road, Newnham, Cambridge.
1908. ‡Smith, E. Shrapnell. 7 Rosebery-avenue, E.C.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1911. §Smith, F. E. National Physical Laboratory, Teddington, Middlesex.
1912. ‡Smith, Rev. Frederick. The Parsonage, South Queensferry.
1897. ‡SMITH, G. ELLIOT, M.D., F.R.S. (Pres. H, 1912), Professor of Anatomy in the University of Manchester.

Year of Election.

1914. §Smith, Mrs. G. Elliot. 4 Willow Bank, Fallowfield, Manchester.
1911. ‡Smith, Geoffrey W., M.A., F.L.S. New College, Oxford.
1903. *SMITH, Professor H. B. LEES, M.A., M.P. The University, Bristol.
1910. §Smith, H. Bompas, M.A. Victoria University, Manchester.
1889. *SMITH, Sir H. LLEWELLYN, K.C.B., M.A., B.Sc., F.S.S. (Pres. F, 1910.) Board of Trade, S.W.
1860. *Smith, Heywood, M.A., M.D. 30 York-avenue, Hove.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., F.R.S., Professor of Pathology in the University of Edinburgh.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.
1914. §Smith, Miss L. Winsford, Kodaikanal, South India.
1914. §Smith, Latimer Elliot. 4 Willow Bank, Fallowfield, Manchester.
1910. §Smith, Samuel. Central Library, Sheffield.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., 19 Manor-road, Sidcup, Kent.
1910. ‡Smith, W. G., B.Sc., Ph.D. College of Agriculture, Edinburgh.
1896. *Smith, Rev. W. Hodson. 104–122 City-road, E.C.
1911. ‡Smith, W. Parnell. The Grammar School, Portsmouth.
1913. ‡Smith, Walter Campbell. British Museum (Natural History), Cromwell-road, S.W.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
1909. ‡Smith, William. 218 Sherbrooke-street, Winnipeg, Canada.
1883. ‡SMITHELLS, ARTHUR, B.Sc., F.R.S. (Pres. B, 1907; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1906. §Smurthwaite, Thomas E., F.R.A.I. 134 Mortimer-road, Kensal Rise, N.W.
1909. ‡Smylie, Hugh. 13 Donegall-square North, Belfast.
1857. *SMYTH, JOHN, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1914. §Smyth, John, M.A., Ph.D. Teachers' College, Carlton, Victoria.
1908. §Smythe, J. A., Ph.D., D.Sc. 10 Queen's-gardens, Benton, Newcastle-on-Tyne.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D. Balholm, Lathom-road, Southport.
1913. *Snell, J. F. C., M.Inst.C.E. 8 Queen Anne's-gate, S.W.
1905. ‡SODDY, F., M.A., F.R.S., Professor of Chemistry in the University of Aberdeen.
1905. ‡Sollas, Miss I. B. J., B.Sc. Newnham College, Cambridge.
1879. *SOLLAS, W. J., M.A., Sc.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900; Council, 1900–03), Professor of Geology in the University of Oxford. 173 Woodstock-road, Oxford.
1900. *SOMERVILLE, W., D.Sc., F.L.S., Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
1910. *Sommerville, Duncan M. Y. The University, St. Andrews, N.B.
1903. ‡Soulby, R. M. Sea Holm, Westbourne-road, Birkdale, Lancashire.
1903. ‡Southall, Henry T. The Graig, Ross, Herefordshire.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1913. §Sparke, Thomas Sparrow. 33 Birkby-crescent, Huddersfield.
1909. ‡Sparling, Rev. J. W., D.D. 159 Kennedy-street, Winnipeg, Canada.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1910. ‡Spearman, C. Birnam, Guernsey.

Year of Election.

1912. §Speers, Adam, B.Sc., J.P. Holywood, Belfast.
1914. §Spence, Mrs. C. J. The Old Hall, Cheadle, Cheshire.
1914. §SPENCER, Professor W. BALDWIN, C.M.G., M.A., D.Sc., F.R.S. The University, Melbourne.
1910. ‡Spicer, Rev. E. C. The Rectory, Waterstock, Oxford.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen-park, Highbury, N.
1894. ‡Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 6 Middle New-street, Fetter-lane, E.C.
1909. ‡Sprague, D. E. 76 Edmonton-street, Winnipeg, Canada.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.
1903. ‡*Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.*
1883. *Stanford, Edward, F.R.G.S. 12-14 Long-acre, W.C.
1914. *Stanley, Hon. Sir Arthur, K.C.M.G. State Government House, Melbourne.
1894. *STANSFIELD, ALFRED, D.Sc. McGill University, Montreal, Canada.
1909. ‡Stansfield, Edgar. Mines Branch, Department of Mines, Ottawa, Canada.
1900. *STANSFIELD, Professor H., D.Sc. Hartley University College, Southampton.
1913. §Stanton, T. E., D.Sc., F.R.S. National Physical Laboratory, Teddington, Middlesex.
1911. §STAPF, Dr. OTTO, F.R.S. Royal Gardens, Kew.
1899. ‡STARLING, E. H., M.D., F.R.S. (Pres. I. 1909; Council, 1914–), Professor of Physiology in University College, London, W.C.
1898. ‡Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
Staveley, T. K. Ripon, Yorkshire.
1907. §Staynes, Frank. 36-38 Silver-street, Leicester.
1910. ‡*Stead, F. B. 80 St. Mary's-mansions, Paddington, W.*
1900. *STEAD, J. E., F.R.S. (Pres. B, 1910.) Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Beech-road, Reigate.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *STEBBING, W. P. D., F.G.S. 78A Lexham-gardens, W.
1914. §STEELE, Professor B. D. The University, Brisbane, Australia.
1911. ‡Steele, L. J., M.I.E.E. H.M. Dockyard, Portsmouth.
1908. ‡Steele, Lawrence Edward, M.A., M.R.I.A. 18 Crosthwaite-park East, Kingstown, Co. Dublin.
1912. §Steggall, J. E. A., M.A., Professor of Mathematics in University College, Dundee. Woodend, Perth-road, Dundee.
1911. ‡Stein, Sir Marc Aurel, K.C.I.E., D.Sc., D.Litt. Merton College, Oxford.
1909. ‡Steinkopj, Max. 667 Main-street, Winnipeg, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1902. ‡Stephenson, G. Grianan, Glasnevin, Dublin.
1910. *STEPHENSON, H. K. Banner Cross Hall, Sheffield.
1911. ‡Stern, Moritz. 241 Bristol-road, Birmingham.
1909. ‡Stethern, G. A. Fort Frances, Ontario, Canada.
1908. *Steven, Alfred Ingram, M.A., B.Sc. 50 Onslow-road, Fairfield, Liverpool.

Year of Election.

1906. ‡Stevens, Miss C. O. The Plain, Foxcombe Hill, Oxford.
1900. ‡STEVENS, FREDERICK. (Local Sec. 1900.) Town Clerk's Office, Bradford.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
1905. §Stewart, A. F. 127 Isabella-street, Toronto, Canada.
1909. ‡Stewart, David A., M.D. 407 Pritchard-avenue, Winnipeg, Canada.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Junior Constitutional Club, Piccadilly, W.
1901. *Stewart, John Joseph, M.A., B.Sc. 2 Stow Park-crescent, Newport, Monmouthshire.
1901. *Stewart, Thomas. St. George's-chambers, Cape Town.
1911. ‡Stibbs, H. A. Portsea Island Gas Company, Commercial-road, Portsmouth.
1913. *STILES, WALTER. The University, Leeds.
1914. §Stillwell, J. L., M.Sc. University of Adelaide, South Australia.
1914. §Stirling, Miss A. M. 48 Melbourne-street, North Adelaide, South Australia.
1914. §STIRLING, E. C., C.M.G., M.A., M.D., F.R.S., Professor of Physiology in the University of Adelaide, South Australia.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Victoria University, Manchester.
1904. ‡Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.
1906. *Stobo, Mrs. Annie. Somerset House, Garelochhead, Dumbartonshire, N.B.
1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1905. ‡Stoneman, Miss Bertha, D.Sc. Huguenot College, Wellington, Cape Province.
1895. *Stoney, Miss Edith A. 20 Reynolds-close, Hampstead Way, N.W.
1908. *Stoney, Miss Florence A., M.D. 4 Nottingham-place, W.
1878. *Stoney, G. Gerald, F.R.S. Oakley, Heaton-road, Newcastle-upon-Tyne.
1883. ‡Stopes, Mrs. 7 Denning-road, Hampstead, N.W.
1903. *STOPES, MARIE C., D.Sc., Ph.D., F.L.S. 14 Well-walk, Hampstead, N.W.
1910. §Storey, Gilbert. Department of Agriculture, Cairo.
1887. *Storey, H. L. Bailrigg, Lancaster.
1888. *Stothert, Percy K. Woolley Grange, Bradford-on-Avon, Wilts.
1905. *Stott, Clement H., F.G.S. P.O. Box 7, Pietermaritzburg, Natal.
1881. ‡STRAHAN, AUBREY, M.A., Sc.D., F.R.S., F.G.S. (Pres. C, 1904), Director of the Geological Survey of Great Britain. Geological Museum, Jermyn-street, S.W.
1905. ‡Strange, Harold F. P.O. Box 2527, Johannesburg.
1908. *Stratton, F. J. M., M.A. Gonville and Caius College, Cambridge.
1914. §Street, Mr. Justice. Judges' Chambers, Supreme Court, Sydney, N.S.W.
1906. *Stromeyer, C. E. 9 Mount-street, Albert-square, Manchester.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M., M.D. 3 Champion-park, Denmark Hill, S.E.

Year of Election.

1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the Armstrong College, Newcastle-upon-Tyne.
1887. *Stroud, William, D.Sc., Professor of Physics in the University of Leeds. Care of Messrs. Barr & Stroud, Anniesland, Glasgow.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Canon Edward A., M.A. The Precincts, Canterbury.
1885. ‡Stump, Edward C. Malmesbury, Polefield, Blackley, Manchester.
1909. ‡Stupart, R. F. Meteorological Service, Toronto, Canada.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1891. *_Sudborough, Professor J. J., Ph.D., D.Sc. University College of Wales, Aberystwyth._
1902. §Sully, H. T. Scottish Widows-buildings, Bristol.
1898. §Sully, T. N. Avalon House, Queen's-road, Weston-super-Mare.
1911. ‡Summers, A. H., M.A. 16 St. Andrew's-road, Southsea.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1908. ‡Sutherland, Alexander. School House, Gersa, Watten, Caithness.
1913. §Sutton, A. M. Bucklebury-place, Woolhampton, Berkshire.
1914. §Sutton, Harvey, M.D., B.Sc. Trinity College, Parkville, Victoria.
1911. §Sutton, Leonard, F.L.S. Hillside, Reading.
1911. ‡Sutton, W. L., F.I.C. Hillcroft, Eaton, Norwich.
1903. ‡Swallow, Rev. R. D., M.A. Chigwell School, Essex.
1905. ‡Swan, Miss Mary E. Overhill, Warlingham, Surrey.
1911. *Swann, Dr. W. F. G. Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D.C., U.S.A.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1914. §Sweet, George, F.G.S. The Close, Brunswick, Victoria.
1914. §Sweet, Miss Georgina, D.Sc. The Close, Brunswick, Victoria.
1913. ‡Swift, Richard H. 4839 St. Lawrence-avenue, Chicago.
1914. §Swinburne, Hon. George. 139 Collins-street, Melbourne.
1887. §Swinburne, James, F.R.S., M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1913. ‡Swinnerton, H. H. 441 Mansfield-road, Nottingham.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1913. §Sykes, Godfrey G. Desert Laboratory, Tucson, Arizona, U.S.A.
1896. *Sykes, Mark L., F.R.M.S. 10 Headingley-avenue, Leeds.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1906. ‡Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1914. §Syme, Mrs. D. York. Balwyn, Victoria.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885. ‡Symington, Johnson, M.D., F.R.S., F.R.S.E. (Pres. H, 1903), Professor of Anatomy in Queen's University, Belfast.
1914. §Symington, Miss N. Queen's University, Belfast.
1908. ‡Synnott, Nicholas J. Furness, Naas, Co. Kildare.

1910. *Tait, John, M.D., D.Sc. 44 Viewforth-terrace, Edinburgh.
1912. ‡Talbot, P. Amaury. Abbots Morton, Inkberrow, Worcestershire.
1904. §Tallack, H. T. Clovelly, Birdhurst-road, South Croydon.
1913. §Tangye, William. Westmere, Edgbaston Park-road, Birmingham.

Year of Election.

1903. *Tanner, Miss Ellen G. Parkside, Corsham, Wilts.
1892. *TANSLEY, ARTHUR G., M.A., F.L.S. Grantchester, near Cambridge.
1908. ‡TARLETON, FRANCIS A., LL.D. 24 Upper Leeson-street, Dublin.
1861. *Tarratt, Henry W. 25 Glyn-mansions, Addison Bridge, Kensington, W.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1913. §Tattersall, W. M., D.Sc. The Museum, The University, Manchester.
1914. *Taylor, C. Z. 216 Smith-street, Collingwood, Victoria.
1908. ‡Taylor, Rev. Campbell, M.A. United Free Church Manse, Wigtown, Scotland.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1881. *Taylor, H. A. 12 Melbury-road, Kensington, W.
1906. ‡Taylor, H. Dennis. Stancliffe, Mount-villas, York.
1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1914. §Taylor, J. M., M.A. Public Service Board, 4 O'Connell-street, Sydney, N.S.W.
1913. ‡Taylor, J. S. The Corinthians, Warwick-road, Acock's Green.
1860. *Taylor, John, M.Inst.C.E. 6 Queen Street-place, E.C.
1906. §Taylor, Miss M. R. Newstead, Blundellsands.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.
1858. ‡TEALE, THOMAS PRIDGIN, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡TEALL, J. J. H., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1893; Council, 1894–1900, 1909–). Athenæum Club, S.W.
1906. *Teape, Rev. W. M., M.A. South Hylton Vicarage, Sunderland.
1910. ‡Tebb, W. Scott, M.A., M.D. 15 Finsbury-circus, E.C.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland Park, Acton, W.
1913. §TEMPLE, Sir R. C., Bart., C.I.E. (Pres. H, 1913.) The Nash, Worcester.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *THANE, GEORGE DANCER, LL.D., Professor of Anatomy in University College, London, W.C.
1871. ‡THISELTON-DYER, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. (Pres. D, 1888; Pres. K, 1895; Council, 1885–89, 1895–1900.) The Ferns, Witcombe, Gloucester.
1906. *THODAY, D. The University, Manchester.
1906. *Thoday, Mrs. M. G. 5 Lyme-park, Chinley, Stockport.
1870. ‡Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street West, Southport.
1891. *Thomas, Miss Clara. Pencerrig, Builth.
1903. *THOMAS, Miss ETHEL N., B.Sc. 3 Downe-mansions, Gondar-gardens, West Hampstead, N.W.
1913. ‡Thomas, H. H., M.A., B.Sc., F.G.S. 28 Jermyn-street, S.W.
1910. *Thomas, H. Hamshaw. Botany School, Cambridge.
1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
1902. *Thomas, Miss M. Beatrice. Girton College, Cambridge.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1904. *Thomas, William, F.R.G.S. Bryn-heulog, Merthyr Tydfil.
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.

Year of Election.

1888. *Thompson, Claude M., M.A., D.Sc., Professor of Chemistry in University College, Cardiff. 38 Park-place, Cardiff.
1885. ‡THOMPSON, D'ARCY W., C.B., B.A. (Pres. D, 1911; Local Sec., 1912), Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1907. *Thompson, Edwin. 25 Sefton-drive, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. *Thompson, G. R., B.Sc., Principal of and Professor of Mining in the South African School of Mines, Johannesburg.
1912. *Thompson, Rev. H. Percy. Kippington Vicarage, Sevenoaks.
1893. *Thompson, Harry J., M.Inst.C.E. Tregarthen, Garland's-road, Leatherhead.
1883. *Thompson, Henry G., M.D. 7 Heathfield-road, Croydon.
1913. *Thompson, Mrs. Lilian Gilchrist. Kippington Vicarage, Sevenoaks.
1913. ‡Thompson, Peter. 14 Rotten Park road, Edgbaston, Birmingham.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1913. *Thompson, Sidney Gilchrist. Kippington Vicarage, Sevenoaks.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S. (Pres. G, 1907; Council, 1897-99, 1910-), Principal of and Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E.C.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., D.Sc. (Local Sec. 1908), King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1911. ‡Thompson, Mrs. W. H. 328 Assiniboine-avenue, Winnipeg.
1912. ‡Thompson, William Bruce. Thornbank, Dundee.
1912. §Thoms, Alexander. 7 Playfair-terrace, St. Andrews.
1894. ‡THOMSON, ARTHUR, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1913. ‡Thomson, Arthur W., D.Sc. 23 Craven Hill-gardens, W.
1912. §Thomson, D. C. 'Courier' Buildings, Dundee.
1909. *Thomson, E. 22 Monument-avenue, Swampscott, Mass., U.S.A.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
1914. §Thomson, Hedley J., Assoc.M.Inst.C.E. 14 Leonard-place, High-street, Kensington, W.
1890. *THOMSON, Professor J. ARTHUR, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡THOMSON, Sir J. J., O.M., M.A., Sc.D., D.Sc., F.R.S. (PRESIDENT, 1909; Pres. A, 1896; Council, 1893-95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1901. ‡*Thomson, Dr. J. T. Kilpatrick.* 148 *Norfolk-street, Glasgow.*
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1902. ‡Thomson, James Stuart. 29 Ladysmith-road, Edinburgh.
1891. ‡Thomson, John. Westover, Mount Ephraim-road, Streatham, S.W.
1871. *THOMSON, JOHN MILLAR, LL.D., F.R.S. (Council, 1895-1901), Professor of Chemistry in King's College, London. 18 Lansdowne-road, Holland Park, W.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1906. ‡Thornely, Miss A. M. M. Oaklands, Langham-road, Bowdon, Cheshire.

Year of Election.

1905. *Thornely, Miss L. R. Nunclose, Grassendale, Liverpool.
1898. *THORNTON, W. M., D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1903. ‡Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. 24 Manville-road, New Brighton, Cheshire.
1898. ‡THORPE, JOCELYN FIELD, Ph.D., F.R.S. Sheffield University.
1871. ‡THORPE, Sir T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1890; Council, 1886–92.) Whinfield, Salcombe, Devon.
1899. §THRELFALL, RICHARD, M.A., F.R.S. Oakhurst, Church-road, Edgbaston, Birmingham.
1896. §THRIFT, WILLIAM EDWARD, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1889. ‡Thys, Colonel Albert. 9 Rue Briderode, Brussels.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 298 Woodstock-road, Oxford.
1905. ‡Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.
1874. ‡TILDEN, Sir WILLIAM A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898–1904.) The Oaks, Northwood, Middlesex.
1913. ‡Tilley, J. W. Field House, Harborne, Park-road, Birmingham.
1899. ‡Tims, H. W. Marett, M.A., M.D., F.L.S., Professor of Biology in the Royal Veterinary College. 11D Oxford and Cambridge-mansions, Marylebone-road, N.W.
1914. §Tims, Mrs. Marett. 11D Oxford and Cambridge-mansions, Marylebone-road, N.W.
1902. ‡Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1911. §Tizard, Henry T. Oriel College, Oxford.
1900. *Tocher, J. F., D.Sc., F.I.C. Crown-mansions, 41½ Union-street, Aberdeen.
1912. §Todd, John A. The Nook, Alexandra Park, Nottingham.
1907. ‡Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1909. ‡Tory, H. M. Edmonton, Alberta, Canada.
1912. ‡Tosh, Elmslie. 11 Reform-street, Dundee.
1901. ‡Townsend, J. S., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1876. *TRAIL, J. W. H., M.A., M.D., F.R.S., F.L.S. (Pres. K, 1910), Regius Professor of Botany in the University of Aberdeen.
1883. ‡TRAILL, A., M.D., LL.D., Provost of Trinity College, Dublin, Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1902. ‡*Travers, Ernest J. Dunmurry, Co. Antrim.*
1914. *Trechmann, C. T. Hudworth Tower, Castle Eden, Durham.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1908. §Treen, Rev. Henry M., B.Sc. Wicken, Soham, Cambridge.
1908. ‡Tremain, Miss Caroline P., B.A. Alexandra College, Dublin.
1910. §TREMEARNE, Major A. J. N., M.A., LL.M. 105 Blackheath-park, S.E.
1911. §Tremearne, Mrs., LL.A., F.L.S. 105 Blackheath-park, S.E.

Year of Election.

1914. §Tremearne, Mrs. Ada J. Mandeville Hall, Clendon-road, Toorak, Victoria.

1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.

1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.

1908. ‡Tresilian, R. S. Cumnor, Eglington-road, Dublin.

1905. ‡TREVOR-BATTYE, A., M.A., F.L.S., F.R.G.S. Stoner Hill, Petersfield, Hants.

1871. ‡TRIMEN, ROLAND, M.A., F.R.S., F.L.S., F.Z.S. Glaslyn, Waterden-road, Guildford.

1902. ‡Tristram, Rev. J. F., M.A., B.Sc. 20 Chandos-road, Chorlton-cum-Hardy, Manchester.

1884. *Trotter, Alexander Pelham. 8 Richmond-terrace, Whitehall, S.W.

1914. §Trouton, Eric. The Rydings, Redington-road, Hampstead, N.W.

1887. *TROUTON, FREDERICK T., M.A., Sc.D., F.R.S. (Pres. A, 1914; Council, 1911-14.) The Rydings, Redington-road, Hampstead, N.W.

1914. §Trouton, Mrs. The Rydings, Redington-road, Hampstead, N.W.

1898. *TROW, ALBERT HOWARD, D.Sc., F.L.S., Professor of Botany in University College, Cardiff.

1913. §Tschugaeff, Professor L. The University, Petrograd.

1885. *Tubby, A. H., M.S., F.R.C.S. 68 Harley-street, W.

1847. *Tuckett, Francis Fox. Frenchay, Bristol.

1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.

1912. ‡Turnbull, John. City Chambers, Dundee.

1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.

1914. §Turner, Dr. A. J. Wickham-terrace, Brisbane, Australia.

1893. ‡TURNER, DAWSON, M.D., F.R.S.E. 37 George-square, Edinburgh.

1913. §Turner, G. M. Kenilworth.

1894. *TURNER, H. H., M.A., D.Sc., F.R.S., F.R.A.S. (GENERAL SECRETARY, 1913- ; Pres. A, 1911), Professor of Astronomy in the University of Oxford. University Observatory, Oxford.

1905. ‡Turner, Rev. Thomas. St. Saviour's Vicarage, 50 Fitzroy-street, W.

1886. *TURNER, THOMAS, M.Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham. 75 Middleton Hall-road, King's Norton.

1863. *TURNER, Sir WILLIAM, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E. (PRESIDENT, 1900; Pres. H, 1889, 1897), Principal of the University of Edinburgh. 6 Eton-terrace, Edinburgh.

1910. *Turner, W. E. S. The University, Sheffield.

1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.

1907. §TUTTON, A. E. H., M.A., D.Sc., F.R.S. (Council, 1908-12.) Duart, Yelverton, South Devon.

1886. *Twigg, G. H. 1 & 2 Ludgate-hill, Birmingham.

1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.

1907. §Twyman, F. 75A Camden-road, N.W.

1865. ‡TYLOR, Sir EDWARD BURNETT, D.C.L., LL.D., F.R.S. (Pres. H., 1884; Council, 1896-1902.) Linden, Wellington, Somerset.

1911. *TYNDALL, A. M., M.Sc. The University, Bristol.

1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.

1912. ‡Tyrrell, G. W. Geological Department, The University, Glasgow.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.

Year of Election.

1903. †Underwood, Captain J. C. 60 Scarisbrick New-road, Southport.
1908. §Unwin, Ernest Ewart, M.Sc. Grove House, Leighton Park School, Reading.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892; Council, 1892–99.) 7 Palace Gate-mansions, Kensington, W.
1909. ‡Urquhart, C. 239 Smith-street, Winnipeg, Canada.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.
1905. ‡Uttley, E. A., Electrical Inspector to the Rhodesian Government, Bulawayo.

1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1912. ‡Valentine, C. W. 103 Magdalen-green, Dundee.
1908. ‡Valera, Edward de. University College, Blackrock, Dublin.
1865. *VARLEY, S. ALFRED. Arrow Works, Jackson-road, Holloway, N.
1907. §VARLEY, W. MANSERGH, M.A., D.Sc., Ph.D. Morningside, Eaton-crescent, Swansea.
1903. ‡Varwell, H. B. Sittaford, West-avenue, Exeter.
1909. *Vassall, H., M.A. The Priory, Repton, Burton-on-Trent.
1907. §Vaughan, Arthur, M.A., D.Sc., F.G.S., Lecturer in Geology at the University of Oxford. The Museums, Oxford.
1905. ‡Vaughan, E. L. Eton College, Windsor.
1913. §Vaughton, T. A. Livery-street, Birmingham.
1881. ‡VELEY, V. H., M.A., D.Sc., F.R.S. 8 Marlborough-place, St. John's Wood, N.W.
1883. *Verney, Lady. Plâs Rhoscolyn, Holyhead.
1904. *Vernon, H. M., M.A., M.D. 5 Park Town, Oxford.
1896. *Vernon, Thomas T. Shotwick Park, Chester.
1896. *Vernon, Sir William, Bart. Shotwick Park, Chester.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1906. *VINCENT, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute, Saltram-crescent, W.
1899. *VINCENT, SWALE, M.D., D.Sc. (Local Sec. 1909), Professor of Physiology in the University of Manitoba, Winnipeg, Canada.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1902. ‡Vinycomb, T. B. Sinn Fein, Shooters Hill, S.E.
1888. *Vogt, Mrs. 478 Uxbridge-road, W.
1904. §Volterra, Professor Vito. Regia Universita, Rome.

1904. §Wace, A. J. B. Pembroke College, Cambridge.
1902. ‡Waddell, Rev. C. H. The Vicarage, Grey Abbey, Co. Down.
1909. ‡Wadge, Herbert W., M.D. 754 Logan-avenue, Winnipeg, Canada.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1914. §Wadsworth, Arthur. Commonwealth Parliament, Melbourne.
1890. §WAGER, HAROLD W. T., F.R.S., F.L.S. (Pres. K, 1905.) Hendre, Horsforth-lane, Far Headingley, Leeds.
1900. ‡Wagstaff, C. J. L., B.A. Haberdashers' School, Cricklewood, N.W.
1902. ‡Wainwright, Joel. Finchwood, Marple Bridge, Stockport.
1906. ‡Wakefield, Charles. Heslington House, York.
1905. §Wakefield, Captain E. W. Stricklandgate House, Kendal.

Year of Election.

1894. ‡WALFORD, EDWIN A., F.G.S. 21 West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. Care of George Lloyd, Esq., 7 Coper's Cope-road, Beckenham, Kent.
1893. ‡Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.
1901. *Walker, Archibald, M.A., F.I.C. Newark Castle, Ayr, N.B.
1897. *WALKER, Sir EDMUND, C.V.O., D.C.L., F.G.S. (Local Sec. 1897. Canadian Bank of Commerce, Toronto, Canada.
1904. §Walker, E. R. Nightingales, Adlington, Lancashire.
1911. *WALKER, E. W. AINLEY, M.A. University College, Oxford.
1905. ‡Walker, Mrs. Ainley. 31 Holywell, Oxford.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1894. *WALKER, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Red Roof, Simla, India.
1897. ‡Walker, George Blake, M.Inst.C.E. Tankersley Grange, near Barnsley.
1913. §Walker, George W., F.R.S. 63 Lensfield-road, Cambridge.
1906. ‡Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
1910. *WALKER, JAMES, D.Sc., F.R.S. (Pres. B, 1911), Professor of Chemistry in the University of Edinburgh. 5 Wester Coates-road, Edinburgh.
1906. §Walker, Dr. Jamieson. 37 Charnwood-street, Derby.
1909. ‡Walker, Lewie D. Lieberose, Monteith-road, Cathcart, Glasgow.
1907. ‡Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W.
1909. §Walker, Mrs. R. 3 Riviera-terrace, Rushbrooke, Queenstown, Co. Cork.
1908. *Walker, Robert. Ormidale, Combe Down, Bath.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1914. §Walkom, A. B. The University, Brisbane, Australia.
1910. ‡Wall, G. P., F.G.S. 32 Collegiate-crescent, Sheffield.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1911. §WALL, THOMAS F., D.Sc., Assoc.M.Inst.C.E. The University, Birmingham.
1905. ‡Wallace, R. W. 2 Harcourt-buildings, Temple, E.C.
1901. ‡Wallace, William, M.A., M.D. 25 Newton-place, Glasgow.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. (Pres. I, 1907.) 32 Grove End-road, N.W.
1905. §Waller, Mrs. 32 Grove End-road, N.W.
1913. *Waller, J. C., B.A. 32 Grove End-road, N.W.
1913. *Waller, Miss M. D., B.Sc., 32 Grove End-road, N.W.
1913. *Waller, W. W., B.A., 32 Grove End-road, N.W.
1895. ‡WALLIS, E. WHITE, F.S.S. Royal Sanitary Institute and Parkes Museum, 90 Buckingham Palace-road, S.W.
1894. *WALMISLEY, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1903. ‡Walsh, W. T. H. Kent Education Committee, Caxton House, Westminster, S.W.
1895. ‡WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1902. *Walter, Miss L. Edna. 38 Woodberry-grove, Finsbury Park, N.
1904. *Walters, William, jun. Albert House, Newmarket.
1887. ‡WARD, Sir A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
1911. ‡Ward, A. W. Town Hall, Portsmouth.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.

Year of Election.

1914. §Ward, L. Keith, B.E. Burnside-road, Kensington Park, South Australia.
1914. §Ward, Thomas W. Endcliffe Vale House, Sheffield.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, Birkenhead.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1887. ‡WARREN, General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres. E, 1887.) Athenæum Club, S.W.
1913. §Warren, William Henry, LL.D., M.Sc., M.Inst.C.E., Challis Professor of Engineering in the University of Sydney, N.S.W.
1913. §Warton, Lieut.-Colonel R. G. St. Helier's, Jersey.
1914. §Waterhouse, G. A., B.Sc. Royal Mint, Sydney, N.S.W.
1875. *WATERHOUSE, Major-General J. Hurstmead, Eltham, Kent.
1905. ‡Watermeyer, F. S., Government Land Surveyor. P.O. Box 973, Pretoria, South Africa.
1900. ‡Waterston, David, M.D., F.R.S.E. King's College, Strand, W.C.
1909. §Watkinson, Professor W. H. The University, Liverpool.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. *WATSON, ARNOLD THOMAS, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1909. §WATSON, Colonel Sir C. M., K.C.M.G., C.B., R.E., M.A. (Pres. E, 1912.) 16 Wilton-crescent, S.W.
1906. ‡Watson, D. M. S. University College, London, W.C.
1909. ‡Watson, Ernest Ansley, B.Sc. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1892. ‡Watson, G., M.Inst.C.E. 5 Ruskin-close, Hampstead-way, N.W.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1906. *Watson, Henry Angus. 3 Museum-street, York.
1913. §Watson, John D., M.Inst.C.E. Tyburn, Birmingham.
1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones House, Beckermet, Cumberland.
1901. ‡Watt, Harry Anderson, M.P. Ardenslate House, Hunter's Quay, Argyllshire.
1913. *Watt, James. 28 Charlotte-square, Edinburgh.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1873. *WATTS, W. MARSHALL, D.Sc. Shirley, Venner-road, Sydenham, S.E.
1883. *WATTS, W. W., M.A., M.Sc., F.R.S., F.G.S. (Pres. C, 1903; Council, 1902-09), Professor of Geology in the Imperial College of Science and Technology, London, S.W.
1870. §Watts, William, M.Inst.C.E., F.G.S. Kenmore, Wilmslow, Cheshire.
1911. ‡Waxweiler, Professor E. Solvay Institute, Brussels.
1905. ‡Way, W. A., M.A. The College, Graaf Reinet, South Africa.
1907. ‡Webb, Wilfred Mark, F.L.S. The Hermitage, Hanwell, W.
1910. ‡Webster, Professor Arthur G. Worcester, Massachusetts, U.S.A.
1910. ‡Webster, William, M.D. 1252 Portage-avenue, Winnipeg, Canada
1904 §Wedderburn, Ernest Maclagan, F.R.S.E. 7 Dean Park-crescent, Edinburgh.
1903 ‡Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1914. §Weir, G. North Mine, Broken Hill, New South Wales.
1890. *WEISS, FREDERICK ERNEST, D.Sc., F.L.S. (Pres. K, 1911; Council, 1914–), Professor of Botany in the Victoria University, Manchester.

Year of Election.

1905. ‡Welby, Miss F. A. Hamilton House, Hall-road, N.W.
1902. ‡Welch, R. J. 49 Lonsdale-street, Belfast.
1894. ‡Weld, Miss. 119 Iffley-road, Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1908. ‡Welland, Rev. C. N. Wood Park, Kingstown, Co. Dublin.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
1911. ‡WELLDON, Right Rev. J. E. C., D.D. (Pres. L, 1911.) The Deanery, Manchester.
1908. ‡*Wellisch, E. M.* 17 *Park-street, Cambridge.*
1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1911. *WELSFORD, Miss E. J. Imperial College of Science, S.W.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. The Limes, Walland's Park, Lewes.
1886. *Wertheimer, Julius, D.Sc., B.A., F.I.C., Dean of the Faculty of Engineering in the University of Bristol.
1910. §WEST, G. S., M.A., D.Sc., Professor of Botany in the University of Birmingham.
1903. ‡Westaway, F. W. 1 Pemberley-crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1909. ‡Wheeler, A. O., F.R.G.S. The Alpine Club of Canada, Sidney, B.C., Canada.
1878. *Wheeler, W. H., M.Inst.C.E. 4 Hope-park, Bromley, Kent.
1893. *WHETHAM, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. ‡Whidborne, Miss Alice Maria. Charanté, Torquay.
1912. §Whiddington, R., M.A., D.Sc. St. John's College, Cambridge.
1913. ‡Whipp, E. M. 14 St. George's-road, St. Anne's-on-Sea.
1912. *Whipple, F. J., M.A. Meteorological Office, South Kensington, S.W.
1898. *WHIPPLE, ROBERT S. Scientific Instrument Company, Cambridge.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council, 1890–96.) 3 Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡WHITE, A. SILVA. Clarendon Lodge, St. John's-gardens, Holland Park, W.
1908. ‡White, Mrs. A. Silva. Clarendon Lodge, St. John's-gardens, Holland Park, W.
1911. ‡White, Miss E. L., M.A. Day Training College, Portsmouth.
1913. §White, Mrs. E. W. Anelgate, Harborne-road, Edgbaston, Birmingham.
1904. ‡White, H. Lawrence, B.A. 33 Rossington-road, Sheffield.
1885. *White, J. Martin. Balruddery, Dundee.
1914. §White, Dr. Jean. Prickly Pear Experimental Station, Dulacca, Queensland, Australia.
1910. *White, Mrs. Jessie, D.Sc., B.A. 49 Gordon-mansions, W.C.
1912. §White, R. G., M.Sc. University College, Bangor, North Wales.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1904. ‡WHITEHEAD, J. E. L., M.A. (Local Sec. 1904.) Guildhall, Cambridge.
1913. ‡Whitehouse, Richard H., M.Sc. Queen's University, Belfast.
1905. ‡Whiteley, Miss M. A., D.Sc. Imperial College of Science and Technology, S.W.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. Municipal Science and Technical School, West Bromwich.
1907. *Whitley, E. 13 Linton-road, Oxford.

Year of
Election.

1905. *Whitmee, H. B. P.O. Box 470, Durban, Natal.
1891. ‡Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
1897. ‡WHITTAKER, E. T., M.A., F.R.S., Professor of Mathematics in the University of Edinburgh.
1901. ‡Whitton, James. City Chambers, Glasgow.
1905. §Wibberley, C., M.V.O. Solheim, Branstone-road, Kew Gardens, Surrey.
1913. §WICKSTEED, Rev. PHILIP H., M.A. (Pres. F, 1913.) Childrey, Wantage, Berkshire.
1912. §Wight, Dr. J. Sherman. 30 Schermerhorn-street, Brooklyn, U.S.A.
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.
1914. §Wilcock, J. L. 9 East-road, Lancaster.
1887. *WILDE, HENRY, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1910. §Wilkins, C. F. Lower Division, Eastern Jumna Canal, Delhi.
1905. ‡Wilkins, R. F. Thatched House Club, St. James's-street, S.W.
1904. ‡Wilkinson, Hon. Mrs. Dringhouses Manor, York.
1900. §Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1913. ‡Willcox, J. Edward, M.Inst.C.E. 27 Calthorpe-road, Edgbaston, Birmingham.
1903. ‡Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.W.
1905. §Williams, Gardner F. 2201 R-street, Washington, D.C., U.S.A.
1883. ‡Williams, Rev. H. Alban, M.A. Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1891. §Williams, J. A. B., M.Inst.C.E. Bloomfield, Branksome Park, Bournemouth.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.
1901. *Williams, Miss Mary. 6 Sloane-gardens, S.W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1883. ‡Williams, T. H. 27 Water-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. Broomgrove, Goring-on-Thames.
1906. ‡*Williams, W. F. Lobb. 32 Lowndes-street, S.W.*
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1894. *Williamson, Mrs. Janora. 18 Rosebery-gardens, Crouch End, N.
1910. ‡Williamson, K. B., Central Provinces, India. Care of Messrs. Grindlay & Co., 54 Parliament-street, S.W.
1913. ‡Willink, H. G. Hillfields, Burghfield, Mortimer, Berkshire.
1895. ‡WILLINK, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.
1895. ‡WILLIS, JOHN C., M.A., F.L.S. Jardin Botanico, Rio de Janeiro.
1896. ‡WILLISON, J. S. (Local Sec. 1897.) Toronto, Canada.
1913. *Wills, L. J., M.A., F.G.S. The University, Birmingham.
1899. §Willson, George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1913. ‡Wilmore, Albert, D.Sc., F.G.S. Fernbank, Colne.
1911. *Wilmott, A. J., B.A. Natural History Museum, S.W.
1911. §Wilsmore, Professor N. T. M., D.Sc. The University, Perth, Western Australia.

Year of Election.

1911. §Wilsmore, Mrs. The University, Perth, Western Australia.
1908. §Wilson, Miss. Glenfield, Deighton, Huddersfield.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1905. ‡Wilson, A. W. P.O. Box 24, Langlaagte, South Africa.
1907. §Wilson, A. W. Low Slack, Queen's-road, Kendal.
1903. ‡Wilson, C. T. R., M.A., F.R.S. Sidney Sussex College, Cambridge.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Suffolk-street, Pall Mall, S.W.
1904. §Wilson, Charles John, F.R.G.S. Deanfield, Hawick, Scotland.
1912. ‡Wilson, David, M.A., D.Sc. Carbeth, Killearn, N.B.
1904. §Wilson, David, M.D. Glenfield, Deighton, Huddersfield.
1912. *Wilson, David Alec. 1 Broomfield-road, Ayr.
1900. *Wilson, Duncan R. 44 Whitehall-court, S.W.
1895. ‡Wilson, Dr. Gregg. Queen's University, Belfast.
1914. §Wilson. H. C. Department of Agriculture, Research Station, Werribee, Victoria.
1901. ‡Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in the Rice Institute, Houston, Texas.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1879. ‡Wilson, Henry J., M.P. Osgathorpe Hills, Sheffield.
1910. *Wilson, J. S. 29 Denbigh-street, S.W.
1913. §Wilson, Professor J. T., M.B., F.R.S. University of Sydney, Sydney, N.S.W.
1908. §Wilson, Professor James, M.A., B.Sc. 40 St. Kevin's-park, Dartry-road, Dublin.
1879. ‡Wilson, John Wycliffe. Easthill, East Bank-road, Sheffield.
1901. *Wilson, Joseph, F.R.M.S. The Hawthorns, 3 West Park-road, Kew Gardens, Surrey.
1908. *Wilson, Malcolm, D.Sc., F.L.S., Lecturer in Mycology and Bacteriology in the University of Edinburgh. Royal Botanic Gardens, Edinburgh.
1909. §Wilson, R. A. Hinton, Londonderry.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. ‡Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
1861. ‡Wilson, Thomas Bright. Ghyllside, Wells-road, Ilkley, Yorkshire.
1887. §Wilson, W. Battlehillock, Kildrummy, Mossat, Aberdeenshire.
1909. ‡Wilson, W. Murray. 29 South Drive, Harrogate.
1910. ‡Wilton, T. R., M.A., Assoc.M.Inst.C.E. 18 Westminster-chambers, Crosshall-street, Liverpool.
1907. §Wimperis, H. E., M.A. 16 Reynolds-close, Hampstead-way, N.W.
1910. ‡Winder, B. W. Ceylon House, Sheffield.
1886. ‡Windle, Sir Bertram C. A., M.A., M.D., D.Sc., F.R.S., President of University College, Cork.
1863. *Winwood, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
1914. §Witkiewicz, S. Care of Dr. Malinowski, London School of Economics, Clare Market, W.C.
1913. ‡Wohlgemuth, Dr. A. 44 Church-crescent, Muswell Hill, N.
1875. ‡Wolfe-Barry, Sir John, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–1903, 1909–10.) Delahay House, 15 Chelsea Embankment, S.W.

Year of Election.

1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Royal Society of Arts, John-street, Adelphi, W.C.; and Prince Edward's-mansions, Bayswater, W.
1908. ‡Wood, Sir Henry J. 4 Elsworthy-road, N.W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1912. §Wood, John K. 304 Blackness-road, Dundee.
1904. *WOOD, T. B., M.A. (Pres. M, 1913), Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James, F.S.A.(Scot.). 266 George-street, Glasgow.
1899. *Woodcock, Mrs. A. Care of Messrs. Stilwell & Harley, 4 St. James'-street, Dover.
1896. *WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
1911. §Woodhead, T. W., Ph.D., F.L.S. Technical College, Huddersfield.
1912. *Wood-Jones, F., D.Sc. New Selma, Epsom, Surrey.
1906. *Woodland, Dr. W. N. F. Zoological Department, The Muir Central College, Allahabad, United Provinces, India.
1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. ‡Woods, Henry, M.A. Sedgwick Museum, Cambridge.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *WOODWARD, ARTHUR SMITH, LL.D., F.R.S., F.L.S., F.G.S. (Pres. C, 1909; Council, 1903–10), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. The Lindens, St. Mary's-road, Harborne, Birmingham.
1912. ‡Woodward, Mrs. C. J. The Lindens, St. Mary's-road, Harborne, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council, 1887–94.) 13 Arundel-gardens, Notting Hill, W
1894. *Woodward, John Harold. 8 Queen Anne's-gate, Westminster, S.W.
1909. *Woodward, Robert S. Carnegie Institution, Washington, U.S.A.
1908. §WOOLACOTT, DAVID, D.Sc., F.G.S. 8 The Oaks West, Sunderland.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.R.C.Inst., F.R.G.S., F.R.E.S., F.S.S., M.R.I.A. 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1914. §Woolnough, Professor W. S., D.Sc. University of Western Australia, Perth, Western Australia.
1912. *Wordie, James M., B.A. St. John's College, Cambridge.
1908. ‡*Worsdell, W. C. 2 Woodside, Bathford, Bath.*
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡Worth, J. T. Oakenrod Mount, Rochdale.
1904. ‡WORTHINGTON, A. M., C.B., F.R.S. 5 Louisa-terrace, Exmouth.
1908. *Worthington, James H., M.A., F.R.A.S., F.R.G.S. The Observatory, Four-Marks, Alton.
1906. ‡WRAGGE, R. H. VERNON. York.
1910. ‡Wrench, E. G. Park Lodge, Baslow, Derbyshire.
1906. ‡Wright, Sir A. E., M.D., D.Sc., F.R.S. 6 Park-crescent, W.
1914. §Wright, A. M. Islington, Christchurch, New Zealand.
1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.

Year of Election.

1909. ‡Wright, C. S., B.A Caius College, Cambridge.
1914. §Wright, Gilbert. Agricultural Department, The University, Sydney, N.S.W.
1874. ‡Wright, Joseph, F.G.S. 4 Alfred-street, Belfast.
1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. Red Gables, Headington Hill, Oxford.
1904. ‡Wright, R. T. Goldieslie, Trumpington, Cambridge
1911. ‡Wright, W. B., B.A., F.G.S. 14 Hume-street, Dublin.
1903. ‡Wright, William. The University, Birmingham.
1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1902. ‡Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1901. ‡Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. ‡Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1911. ‡Wyllie, W. L., R.A. Tower House, Tower-street, Portsmouth.
1899. ‡WYNNE, W. P., D.Sc., F.R.S. (Pres. B, 1913), Professor of Chemistry in the University of Sheffield. 17 Taptonville-road, Sheffield.

1901. *YAPP, R. H., M.A., Professor of Botany in Queen's College, Belfast.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Campsie Dene, Blanefield, Stirlingshire.
1913. *Yates, H. James, F.C.S., M.I.Mech.E. Redcroft, Four Oaks, Warwickshire.
1905. ‡Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W.
1909. §Young, Professor A. H. Trinity College, Toronto, Canada.
1904. ‡Young, Alfred. Selwyn College, Cambridge.
1891. §YOUNG, ALFRED C., F.C.S. 17 Vicar's-hill, Lewisham, S.E.
1905. ‡Young, Professor Andrew, M.A., B.Sc. South African College, Cape Town.
1909. ‡Young, F. A. 615 Notre Dame-avenue, Winnipeg, Canada.
1913. *Young, Francis Chisholm. La Nonette de la Forêt, Geneva.
1894. *YOUNG, GEORGE, Ph.D. 46 Church-crescent, Church End, Finchley, N.
1909. §Young, Herbert, M.A., B.C.L., F.R.G.S. Arnprior, Ealing, W.
1901. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1885. ‡YOUNG, R. BRUCE, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow.
1909. ‡Young, R. G. University of North Dakota, North Chautauqua, North Dakota, U.S.A.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1911. ‡Young, T. J. College of Agriculture, Holmes Chapel, Cheshire.
1907. *YOUNG, WILLIAM HENRY, M.A., Sc.D., Hon. Dr. ès Sc. Math., F.R.S., Professor of the Philosophy and History of Mathematics in the University of Liverpool. La Nonette de la Forêt, Geneva, Switzerland.
1903. ‡Yoxall, Sir J. H., M.P. 67 Russell-square, W.C.

LIST OF MEMBERS WHO JOINED IN AUSTRALIA, 1914.

* indicates Life Members.
§ indicates Old Annual Members, and New Annual Members who joined for more than one centre.

ADELAIDE.

Adams, J. R. G. Public Library, Adelaide.
*Alexander, W. B., M.A. Western Australian Museum, Perth, West Australia.
Angel, F. M. 34 Fullarton-road, Parkside, South Australia.
Angel, Sidney. Commercial Bank, Norwood, South Australia.
Angus, W., M.P. Parliament House, South Australia.
Ashby, Edwin. Wittunga, Blackwood, South Australia.

Baker, W. H. Glen Osmond-road, Parkside, South Australia.
Bakewell, Leonard W. Fitzroy-terrace, Prospect, South Australia.
Barker, John. 61 Currie-street, Adelaide.
Barlow, Wm., C.M.G., LL.D. Lefevre-terrace, North Adelaide.
Basedow, B. Horndale Vineyard, O'Halloran Hill, South Australia.
Basedow, Herbert, M.A., M.D., B.Sc., F.G.S. Pirie-street, Kent Town, South Australia.
Benham, Miss E. I., B.Sc. Victoria-avenue, Unley Park, South Australia.
Benham, E. W., LL.B. Unity-chambers, Currie-street, Adelaide.
Bevan, Rev. Llewellyn D., LL.B., B.D. Parkin College, Kent Town, South Australia.
Bevan, Mrs. Ll. D. Parkin College, Kent Town, South Australia.
Birks, Mrs. Napier. Park-terrace, Parkside, South Australia.
Bollen, Percival, M.D. Semaphore, South Australia.
Bonython, The Hon. Sir J. Langdon. Carclew, North Adelaide.
Booth, Dr. James. 47 Strangways-terrace, North Adelaide.
Booth, S. Russell, B.A. East-terrace, Adelaide.
Bowman, J. Yateena, First Avenue, Joslin, South Australia.
Bowman, Mrs. T. R. Waverley, South-terrace, Adelaide.
Brand, Major C. H. Military Headquarters, West Wayville, South Australia.
Bright, Rev. Chas. William-street, Norwood, South Australia.
Brookman, George. Brookman's-building, Grenfell-street, Adelaide.
Brown, H. Y. L. 286 Ward-street, North Adelaide.
Brown, Mrs. H. Y. L. 286 Ward-street, North Adelaide.
Brown, Professor William Jethro, LL.D., D.Litt. University, Adelaide.
Browne, J. W., M.B., B.Ch. Hutt-street, Adelaide.
Browne, Bro. P. Paringa Hall, Brighton-road, Glenelg.
Brummitt, Dr. R. Northcote-terrace, Medindie, South Australia.
Buchanan, Mr. Justice. Supreme Court, Adelaide.
Bull, Lionel B. Adelaide Hospital, South Australia.
§Bundey, Miss E. M. Molesworth-street, North Adelaide.
Burford, W. Sea Wall, Glenelg, South Australia.
Burgess, Rev. Dr. Charles-street, Norwood, South Australia.
Burgess, Miss M. 112 South-terrace, Adelaide.
Burston, Dr. S. R. Henley Beach-road, Mile End, South Australia.

Chapman, Professor R. W., M.A., B.C.E. University of Adelaide, Burnside, South Australia.
Chapple, Frederic, B.A., B.Sc. Kent Town, South Australia.
Chapple, Dr. Phœbe. Kent Town, South Australia.
Clark, E. V., B.Sc. Knightsbridge, South Australia.

Cleland, E. E. Church-terrace, Walkerville, South Australia.
Connor, J. D., B.Sc. 24 Barnard-street, North Adelaide.
§Cooke, William Ternant, D.Sc. Fourth-avenue, East Adelaide.
Corbin, H. H., B.Sc. University, Adelaide.
Corbin, John, M.R.C.S., L.R.C.P. Brougham-place, North Adelaide.
Corpe, J. R. Kingston-terrace, North Adelaide.
Corpe, Mrs. J. R. Kingston-terrace, North Adelaide.
Counter, E. J., D.D.S. 20 North-terrace, Adelaide.
Crespigny, C. T. Champion de, M.D. 132 Strangways-terrace, North Adelaide.

Denny, W. J., M.P. South-terrace, Adelaide.
Downer, Frank H. Citizens'-buildings, King William-street, Adelaide.
Downer, Mrs. F. H. Citizens'-buildings, King William-street, Adelaide.
Downer, Hon. Sir John, K.C.M.G., K.C., M.L.C. Pennington-terrace, North Adelaide.
§Duffield, D. W. 13 Cowra-chambers, Grenfell-street, Adelaide.
Duffield, Mrs. D. W. Sea Wall, Glenelg, South Australia.
Duncan-Hughes, J. G., M.A. 20 Robe-terrace, Medindie, South Australia.

Ellery, T. Geo. Town Hall, Adelaide.

Finlayson, Miss. Sea Wall, Glenelg, South Australia.
Finlayson, Mrs. L. M. Sea Wall, Glenelg, South Australia.
Fisher, C. H. The Avenue, Medindie, South Australia.
Fry, H. Kenneth, B.Sc., M.B. Parade, Norwood, South Australia.
Fuller, Wm. University of Adelaide, South Australia.

Gartrell, H. W., M.A., B.Sc. Henry-street, Payneham, South Australia.
Gault, A. H., M.D. Lower Mitcham, South Australia.
Gibson, Jas. A. Messrs. Cowell Bros., Victoria-square, Adelaide.
Gifford, Rev. A. E. 25 Stanley-street, North Adelaide.
Giles, F. W. Royal Geographical Society, North-terrace, Adelaide.
Giles, Mrs. T. O'H. Pier-street, Glenelg.
Gill, Thos., I.S.O. The Treasury, Adelaide.
Gill, Walter. Malvern, South Australia.
Goodman, W. G. T., M.I.C.E., M.I.E.E. Strangways-terrace, North Adelaide.
§Grant, Kerr, M.Sc., Professor of Physics in the University of Adelaide.
§Grasby, W. C. C/o G. J. W. Grasby, Grenfell-street, Adelaide.

Hackett, W. Champion. 54 Flinders-street, Kent Town, South Australia.
Halcomb, G. W., B.A. Eagle-chambers, Pirie-street, Adelaide.
Halley, Dr. Gertrude. Wellington-road, Maylands, South Australia.
§Happell, Mrs. C/o Miss E. M. Bundey, Molesworth-street, North Adelaide.
Hargrave, A. A. 144 Barton-terrace, North Adelaide.
Hargrave, C. T. Kermode-street, North Adelaide.
Hargreaves, W. A., B.Sc. Giles-street, Rose Park East, South Australia.
Haslam, J. A., B.Sc. Prince Alfred College, Adelaide.
Hawker, E. W., M.A., LL.B. East Bungaree, Clare, South Australia.
Hawker, Mrs. E. W. East Bungaree, Clare, South Australia.
Hawkes, J. H. M. Messrs. D. & J. Fowler, Adelaide.
Hawkes, R. J. E. S. & A. Bank, King William-street, Adelaide.
Hodge, Charles R., Registrar, University of Adelaide.
Holtze, Maurice William, I.S.O., F.L.S., Director Botanical Gardens, Adelaide.
Hone, F. S., B.A., M.B. Semaphore, South Australia.
Hosking, J. W. Parade, Norwood, South Australia.
Howard, Rev. Henry. Pirie-street, Adelaide.
Howchin, Walter. University of Adelaide.
§Hughes, Herbert W. Adelaide Club, Adelaide.
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1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
1889. Wladimir Vernadsky. Imperial Academy of Sciences, Petrograd.
1913. Professor M. Verworn. Universität, Bonn.
1886. Professor Jules Vuylsteke. 21 rue Belliard, Brussels, Belgium.
1887. Professor Dr. Leonhard Weber. Moltkestrasse 60, Kiel.
1913. Professor Max Weber. Universiteit, Amsterdam.

Year of Election.

1887. Dr. H. C. White. Athens, Georgia, U.S.A.
1881. Professor H. M. Whitney. Branford, Conn., U.S.A.
1887. Professor E. Wiedemann. Erlangen.
1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Dr. Otto N. Witt. Ebereschen-Allée 10, Westend bei Berlin.
1913. Professor R. W. Wood. Johns Hopkins University, Baltimore, U.S.A.
1913. Professor P. Zeeman. Universiteit, Amsterdam.

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TO WHICH A COPY OF THE REPORT IS PRESENTED.

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Belfast, Queen's University.
Birmingham, Midland Institute.
Bradford Philosophical Society.
Brighton Public Library.
Bristol Naturalists' Society.
——, The Museum.
Cambridge Philosophical Society.
Cardiff, University College.
Chatham, Royal Engineers' Institute.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Irish Academy.
——, Royal Society.
——, National Library of Ireland.
Dundee, University College.
——, Albert Institute.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Royal Albert Memorial College Museum.
Glasgow, Royal Philosophical Society of.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Institute of Science.
——, Philosophical and Literary Society of.
Liverpool, Free Public Library.
——, Royal Institution.
——, The University.
London, Admiralty, Library of the.
——, Board of Agriculture and Fisheries.
——, Chemical Society.
——, Civil Engineers, Institution of.
——, Geological Society.
——, Geology, Museum of Practical.
——, Greenwich Royal Observatory.
——, Guildhall Library.
——, Institution of Electrical Engineers.
——, Institution of Mechanical Engineers.
——, Intelligence Office, Central Department of Political Information.
London, King's College.
——, Linnean Society.
——, London Institution.
——, Meteorological Office.
——, Physical Society.
——, Royal Anthropological Institute.
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Geographical Society.
——, Royal Institution.
——, Royal Meteorological Society.
——, Royal Sanitary Institute.
——, Royal Society.
——, Royal Society of Arts.
——, Royal Statistical Society.
——, United Service Institution.
——, University College.
——, War Office, Library.
——, Workers' Educational Association.
——, Zoological Society.
Manchester Literary and Philosophical Society.
——, Municipal School of Technology.
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Natural History Society.
——, Radcliffe Observatory.
Plymouth Institution.
——, Marine Biological Association.
Salford, Royal Museum and Library.
Sheffield, University College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Surrey, Royal Gardens, Kew.
——, Kew Observatory, Richmond.
Swansea, Royal Institution of South Wales.
Yorkshire Philosophical Society.
The Corresponding Societies.

EUROPE.

Berlin ....Die Kaiserliche Akademie der Wissenschaften.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra .....Meteorological Observatory.
Copenhagen...Royal Society of Sciences.
Dorpat, Russia University Library.
Dresden ....Royal Public Library.
Frankfort ...Natural History Society.
Geneva.......Natural History Society.
Göttingen ....University Library.
Grätz ....Naturwissenschaftlicher Verein.
Halle ....Leopoldinisch - Carolinische Akademie.
Harlem ......Société Hollandaise des Sciences.
Heidelberg....University Library.
Helsingfors ...University Library.
Jena ....University Library.
Kazan, Russia University Library.
Kiel ....Royal Observatory.
Kiev ....University Library.
Lausanne ....The University.
Leiden ....University Library.
Liége ....University Library.
Lisbon ....Academia Real des Sciences.
Milan ....The Institute.
Modena ......Royal Academy.
Moscow ......Society of Naturalists.
—— ......University Library.
Munich.......University Library.
Naples ....Royal Academy of Sciences.
—— ....Zoological Station.
Paris.........Association Française pour l'Avancement des Sciences.
—— ....Geographical Society.
—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Petrograd ....University Library.
—— ....Imperial Observatory.
Pultova ......Imperial Observatory.
Rome ....Accademia dei Lincei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
Rumania ....Rumanian Association for the Advancement of Science.
Spain ....Asociacion para el Progreso de las Ciencias.
Stockholm ...Royal Academy.
Turin ....Royal Academy of Sciences.
Upsala ......Royal Society of Science.
Utrecht ......University Library.
Vienna ......The Imperial Library.
—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich........Naturforschende Gesellschaft.

ASIA.

Agra ....The College.
Bombay .....Elphinstone Institution.
—— ....Grant Medical College.
—— ....Royal Asiatic Society.
Calcutta .....Royal Asiatic Society.
—— ....Hooghly College.
Calcutta .....Medical College.
—— ....Presidency College.
Ceylon ....The Museum, Colombo.
Madras ......The Observatory.
—— ....University Library.
Tokyo ....Imperial University.

AFRICA.

Cape Town ....National Botanic Gardens, Newlands.
—— ....The Royal Observatory.
—— ....South African Association for the Advancement of Science.
—— ....South African Public Library.
Grahamstown ..Rhodes University College.
Kimberley ....Public Library.

AMERICA.

Albany ......The Institute.
Amherst......The Observatory.
Baltimore ....Johns Hopkins University.
Boston ......American Academy of Arts and Sciences.
—— ....Boston Society of Natural History.
California.....The University.
—— ......Lick Observatory.
—— ......Academy of Sciences.
Cambridge ...Harvard University Library.
Chicago ......American Medical Association.
—— ....Field Museum of Natural History.
Edmonton....University of Alberta.
Kingston .....Queen's University.
Manitoba ....Historical and Scientific Society.
—— ....The University.
Massachusetts .Marine Biological Laboratory, Woods Holl.
Mexico ......Sociedad Científica 'Antonio Alzate.'
Missouri .....Botanical Garden.
Montreal .....Council of Arts and Manufactures.
Montreal .....McGill University.
New York ...American Society of Civil Engineers.
—— ....Academy of Sciences.
Ottawa.......Geological Survey of Canada.
Philadelphia ..American Philosophical Society.
—— ....Franklin Institute.
—— ....University of Pennsylvania.
Toronto .....The Observatory.
—— ....The Canadian Institute.
—— ....The University.
Uruguay......General Statistical Bureau and Library, Montevideo.
Washington...Board of Agriculture.
—— ....Bureau of Ethnology.
—— ....Bureau of Standards, Department of Commerce and Labour.
—— ....Coast and Geodetic Survey.
—— ....Library of Congress.
—— ....Naval Observatory.
—— ....Smithsonian Institution.
—— ....United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide ....Public Library of South Australia.
—— ....Royal Geographical Society.
Brisbane ....Queensland Museum.
—— ....Queensland Public Library.
Melbourne ....Public Library.
Sydney ....Public Works Department.
—— ....Australian Museum.
—— ....Library, Department of Mines.
Tasmania ....Royal Society.
Victoria............The Colonial Government.

NEW ZEALAND.

Canterbury ....The Museum.
Wellington ....New Zealand Institute (Dominion Museum).

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